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Spacelab Level IV Programmatic Implementation Assessment Study

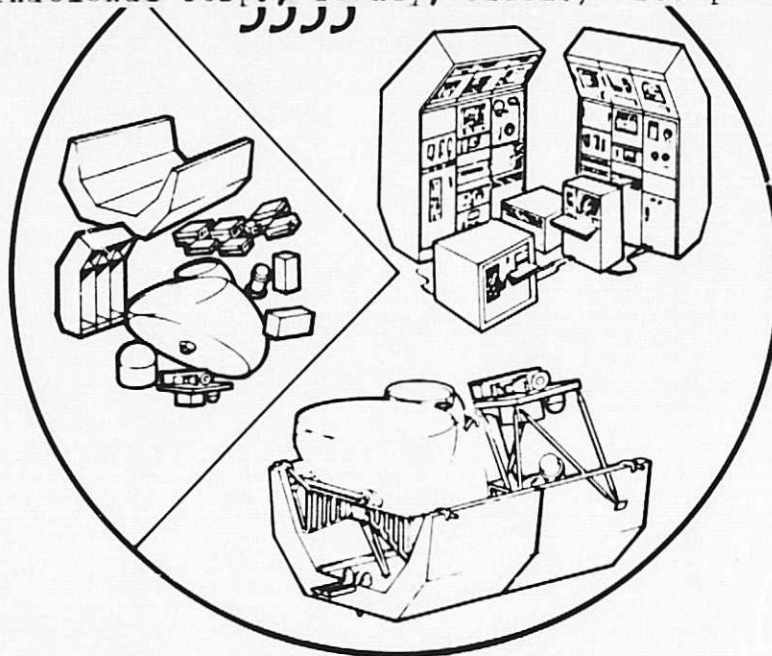
(NASA-CR-145348-vol-1) SPACELAB LEVEL 4
PROGRAMMATIC IMPLEMENTATION ASSESSMENT
STUDY. VOLUME 1: REPRESENTATIVE PAYLOAD
DEFINITION Final Report (Rockwell
International Corp., Downey, Calif.) 206 p G3/12

N78-29119

Unclas
27251

FINAL
REPORT

MAY
1978



Volume I

Representative Payload Definition

PREPARED UNDER CONTRACT NO. NAS1-14909

BY



Rockwell International

Space Division

FOR

NASA

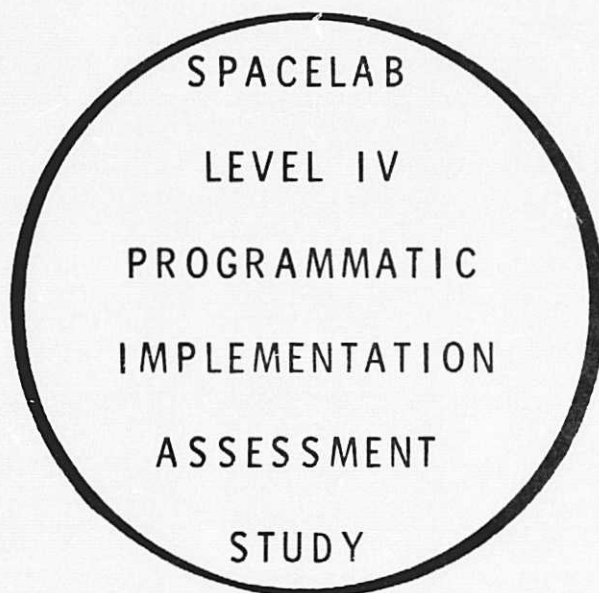
National Aeronautics and
Space Administration

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FINAL REPORT

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Volume I

Representative Payload Definition

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(Paragraph F, Part III)
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ACKNOWLEDGEMENT

The Spacelab Level IV Programmatic Implementation Assessment Study was conducted for NASA's Langley Research Center by the Space Division of Rockwell International Corporation under Contract NAS1-14909. Mr. F. O. Allamby was the technical study manager for the Langley Research Center. Mr. Allamby's contributions to the technical content and assistance in the establishment of study concepts and the final analysis of alternatives was extremely beneficial and enhanced the final study products greatly. In addition, Dr. Dale Compton, as chairman of the Technical Advisory Committee, provided valuable assistance to the study with his scientific and technical support.

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FOREWORD

The Spacelab Level IV Programmatic Implementation Assessment Study was conducted to assess the Level IV payload integration requirements. In the study, alternate Level IV integration approaches were synthesized and evaluated to establish the most cost-effective experiment integration approach. Resource requirements or cost factors that were included in the assessment pertained to the "hands-on" activities of ground processing. These requirements included manpower, temporary duty subsistence and air fare, flight hardware and Ground Support Equipment (GSE) transportation costs, and prorated flight hardware and GSE use costs based upon the involvement time of these items for each mission. Programmatic inventories of flight hardware and GSE were developed using representative payloads. These payloads were defined to a level of detail that permitted a detailed assessment of the handling, installation, servicing and checkout requirements of the experiment end items. Spacelab flight hardware and GSE support and interface requirements were identified. Buildup schedules for the inventories were formulated. Alternate ground processing concepts were synthesized and the processing of each of the representative payload through these concepts was evaluated. Cost data for each processing option was developed for each payload. The spectrum of experiments and payloads used in the study facilitated the identification of design characteristics to identify the ground processing activities. Guidelines were identified to assist experimenters in the development of payload designs that will permit cost-effective ground processing.

The results of the Spacelab Level IV Programmatic Implementation Assessment Study effort are presented in four volumes:

VOLUME I	REPRESENTATIVE PAYLOAD DEFINITION	SD 78-SR-0009-1
VOLUME II	GROUND PROCESSING REQUIREMENTS	SD 78-SR-0009-2
VOLUME III	OPTIMIZATION AND PROGRAMMATICS	SD 78-SR-0009-3
VOLUME IV	EXECUTIVE SUMMARY	SD 78-SR-0009-4



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1.0 INTRODUCTION

In order to provide a broad spectrum of Level IV integration ground processing requirements, four types of Spacelab payloads were analyzed in this study. These payloads are considered to be representative of the Spacelab traffic model. The payloads analyzed were:

- | | |
|-----------------------------------|--|
| 1. Space Processing. | A single pallet payload that is representative of materials development and industrial applications activities, which would be part of a mixed cargo Orbiter flight. |
| 2. Combined Astronomy. | A five pallet payload that is representative of astrophysics, solar terrestrial, and astronomy investigations. |
| 3. Life Sciences. | A long module payload that is representative of aerospace bioscience and physiological investigations. |
| 4. Advanced Technology Laboratory | A short module plus pallet train payload that is representative of multi-disciplined technological investigations. |

Experiments and configurations for these types of payloads were defined to various levels of detail in previous NASA and contractor studies. In this study, these data were expanded and integrated into representative payloads to a depth that would permit assessment of ground processing activities. A synopsis of the experiments and flight configuration for each of the four representative payloads is presented in subsequent sections of this volume. A detailed description of each of the experiments for each payload is presented in the appendixes, under separate cover.

A brief description of the Spacelab components which played a major role in this study is presented in an included appendix to this volume. Similarly found are the definitions for the four levels of payload integration.

2.0 SPACE PROCESSING PAYLOAD

INTRODUCTION

The representative single pallet/mixed cargo Spacelab payload used in this study was an adaptation of the Space Processing payload defined in previous NASA studies, including contract NAS8-31495. The other cargo elements considered were Solid Spinning Upper Stage-D (SSUS-D) with a Telsat and a Small Business Satellite payload. A Spacelab mixed cargo was included to assess potential implications of such a configuration on Level IV ground processing activities.

Mixed Cargo Implications

An assessment of the potential interactions between a Spacelab payload and free-flyers on Spacelab Level IV integration was conducted. Scheduling, mission planning, resource management, thermal and structural analysis; crew training, and Kennedy Space Flight Center-Space Transportation System (KSC-STS) operations will be affected by a mixed cargo configuration. These impacts will be reflected in the analytical engineering and integration activities of Level IV integration. However, Level IV ground processing, which is the only Level IV integration activity addressed in this study, will not be affected by a mixed cargo configuration. Flight hardware, ground support equipment, personnel, transportation, and facilities required to conduct Spacelab Level IV ground processing are distinctly separated from the comparable resources required to support the ground processing of free-flyers.

Ground processing interfaces between a Spacelab and free-flyers do not occur prior to KSC-STS operations. Even during STS operations, these interfaces will be limited. Spacelab/mixed cargo flights that occur in the initial phase of the program may require compatibility assessment in the Cargo Interface Test Equipment (CITE) facility. As the program matures, it is doubtful if a Spacelab payload will be processed in CITE with free-flyers. Except for scheduling, transportation to the Orbiter Processing Facility (OPF) and installation in the Orbiter of a Spacelab payload and free-flyers will be independent. Most of the free-flyers, particularly those requiring an Interim Upper Stage or Solid Spinning Upper Stage, will be installed at the launch pad rather than the OPF due to safety requirements.

Significant ground processing interfaces between a Spacelab payload and free-flyers were identified during only two STS operations activities; installation and checkout of Orbiter aft-flight-deck controls and displays (for the cargo), and final servicing and interface verification of cargo elements at the pad. Neither of these activities impose constraints/requirements on the Level IV ground processing activities of a Spacelab payload.

Payload Adaptation

Although the basic experiment equipment defined in the "Space Processing Payload Equipment Study", Contract NAS8-31495, was used, a major revision to the payload



configuration was made for purposes of this study. In the referenced study, the experiment equipment was integrated into a shroud assembly that was subsequently mounted on a pallet (Figure 2-1). In this study, Level IV ground processing was defined as being initiated with the installation of experiment equipment in/on Spacelab mounting element and completed upon delivery of the integrated experiments/payload to the Operations and Checkout (O&C) building at KSC. If the referenced configuration were used, then the Level IV ground processing activity would be a relatively minor activity; only the installation of the shroud assembly to the pallet would be applicable. The guidelines of this study would classify the installation and checkout of the experiment equipments in the shroud assembly as a Level V integration activity.

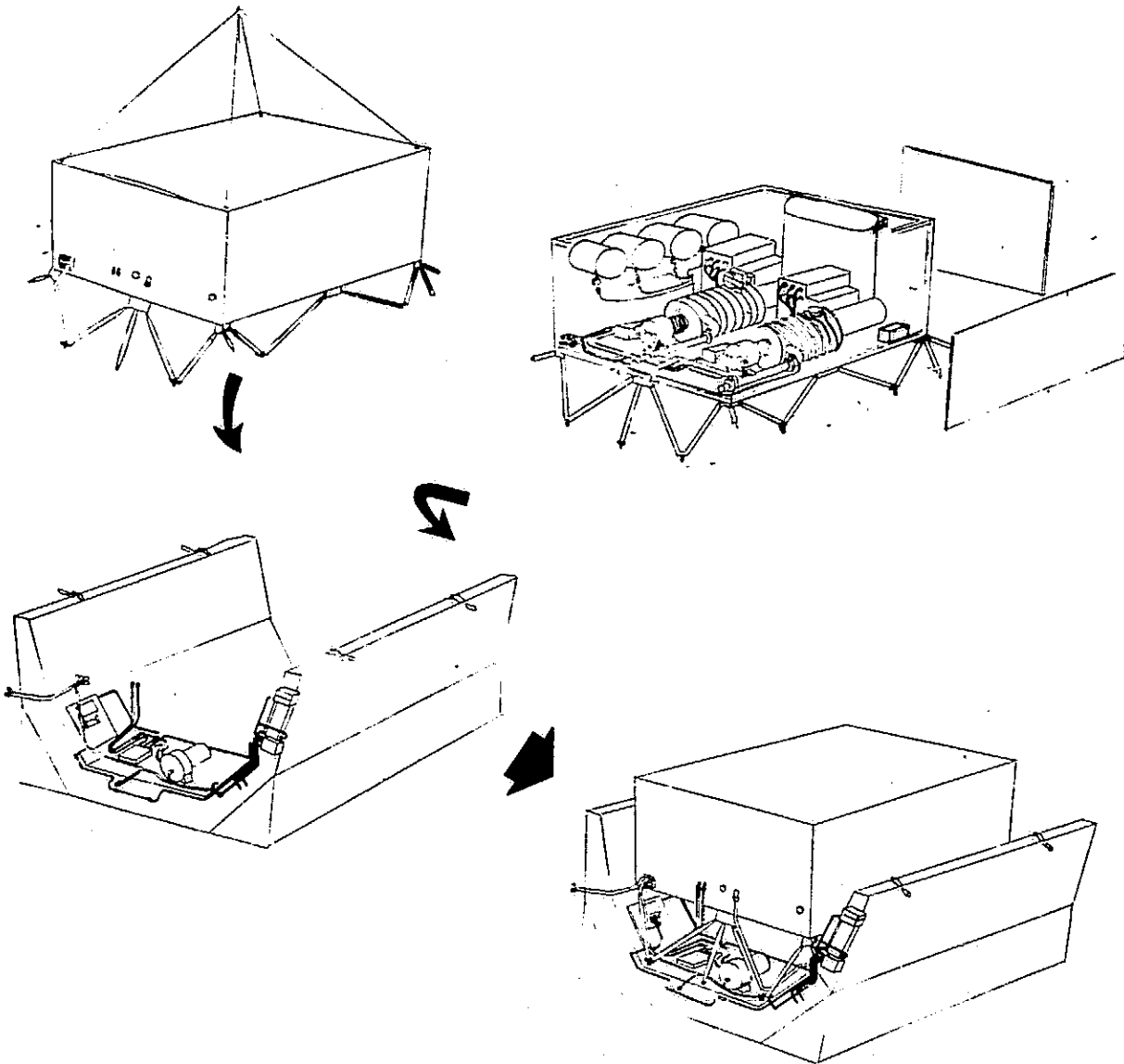


Figure 2-1. Shroud Assembly and Installation - Space Processing

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For purposes of this study, the configuration was modified. All experiment equipments that were mounted in the shroud assembly were mounted directly to the pallet segment; the shroud assembly was deleted (Figure 2-2).

The direct mounting of these equipments to the pallet may not be practical for these particular experiments. However, it is believed that this type of pallet only configuration is more indicative of the Space Processing type payloads of the Spacelab traffic model.

A second major change to the referenced configuration was required because of limited control and display panel area/volume in the Orbiter aft-flight-deck. Controls and displays for the various experiments/facilities were combined and some command/display functions were incorporated in the Spacelab Command and Data Management System (CDMS). The resulting aft-flight-deck equipment is illustrated in Figure 2-3. It is not the intent of this illustration to identify the specific location of the equipment. That would be based on the combined requirements of the Space Processing payload, Spacelab systems, and the free-flyers.



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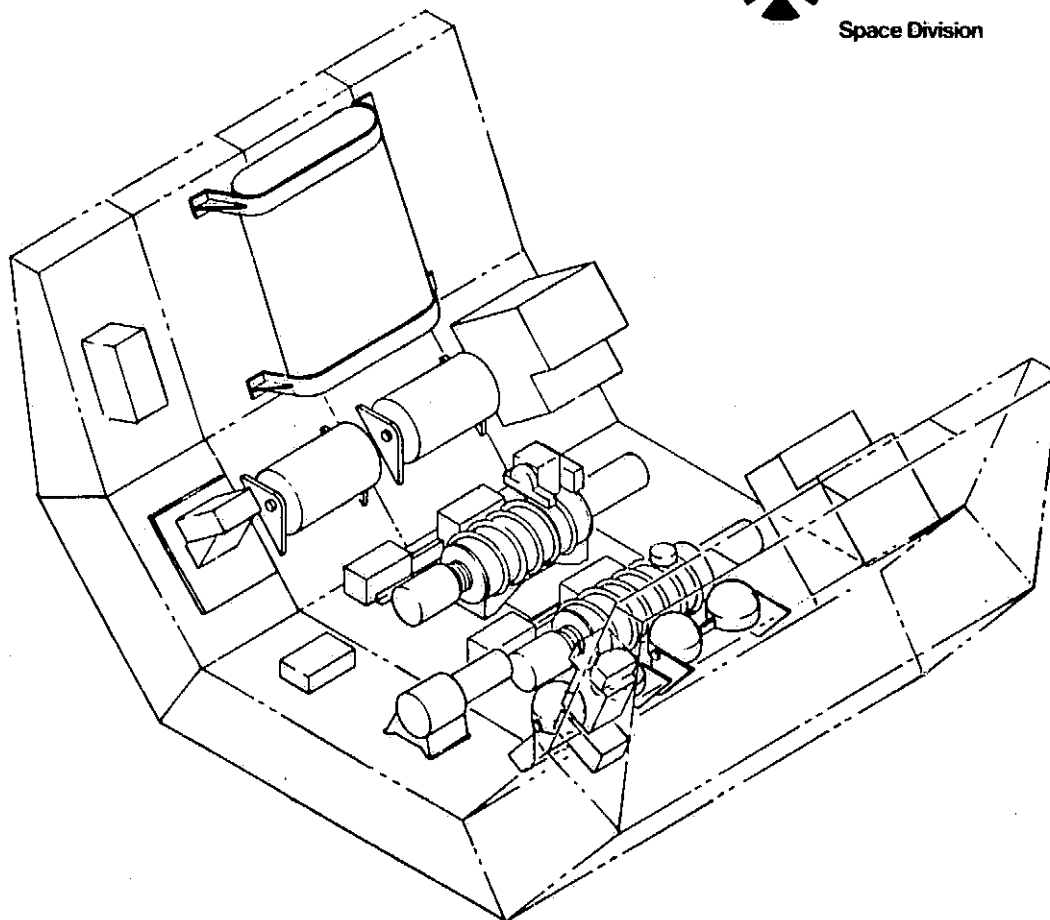
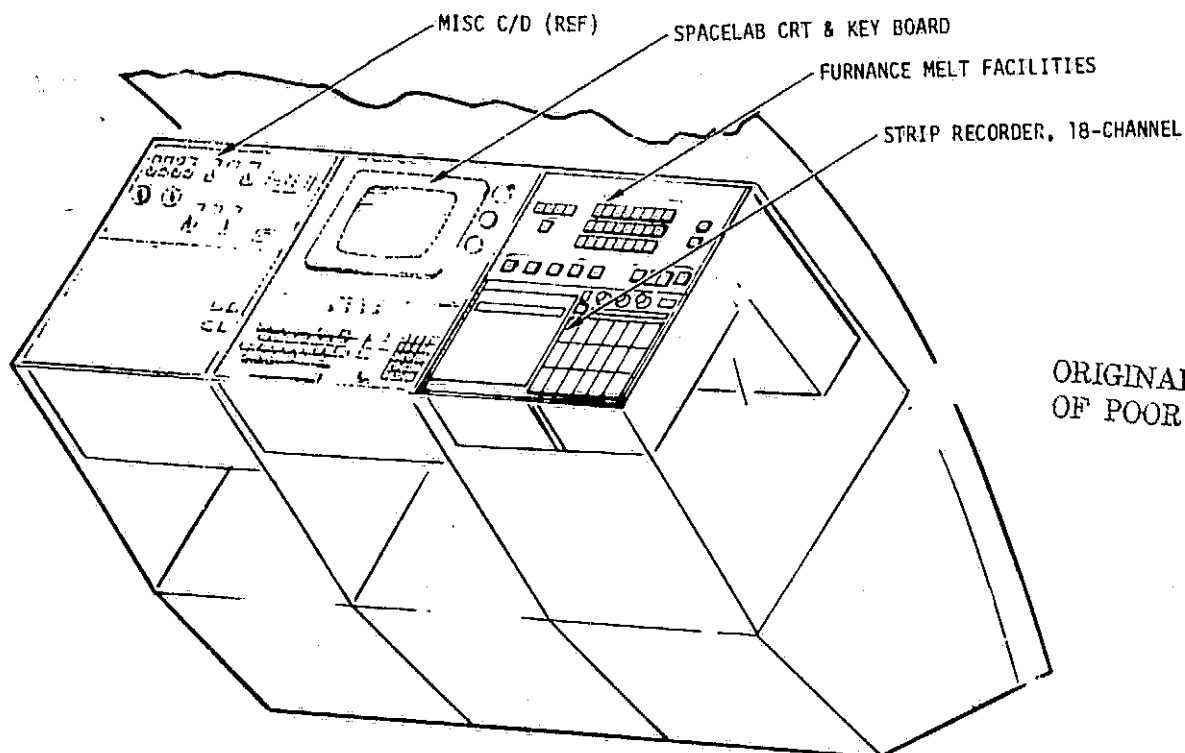


Figure 2-2. Revised Space Processing Payload Configuration



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Figure 2-3. Space Processing Payload AFD Equipment



EXPERIMENT COMPLEMENT

The experiments included in the Space Processing payload are listed in Table 2-1. The eleven experiments are divided into four groups that correspond to four experimental space processing facilities. Each group of experiments is conducted within its corresponding facility. Detailed descriptions of each experiment and its associated equipment are presented in the Ground Processing Requirements Experiment Definition Package (GPR EDP) in Appendix A. A synopsis of the experiments and facilities is presented in subsequent paragraphs.

Table 2-1. Experiment Complement for Space Processing Payload

Experiment	Facility
S9A Evaporative Purification of Metals S9B Controlled Solidification Morphologies S21 Evaporative Purification	Electromagnetic Levitation Positioning Melt Facility ① (3 chambers)
C/G5 Containerless Melting of Blanks for Fiber Optics C/G7 Space Processing of Chalcogenide Glasses	Acoustic Levitation Positioning Melt Facility ①
S4 Preparation of High Point Defect Density Epitaxial Films S7 Crystal Growth or Solidification of Material S14 Crystal Growth by Chemical Vapor Transport	Multipurpose Furnace/Crystal Growth Melt Facility
S6 Floating Zone Melt of Silicon S16 Crystal Growth from Quiescent Melt S25 Containerless Zone Growth of Al ₅ Si	Float Zone Refining/Crystal Growth Facility
① Modified Space Processing Application Rocket (SPAR) facility.	



Electromagnetic Levitation Positioning Melt Facility

An electromagnetic containerless facility with three processing chambers is used (Figure 2-4). Each chamber is sequentially activated by switching all power, coolant, and command/data services from one chamber to another to process each specimen within its own chamber. This processing technique requires an r.f. induction coil to melt the specimen by inducing electrical currents in the specimen material. A sensing and feedback system is also included in the coil control system to position and maintain the molten specimen in "free space" within the chamber. Contact of the molten specimen with the coil, chamber walls or any other object is inhibited.

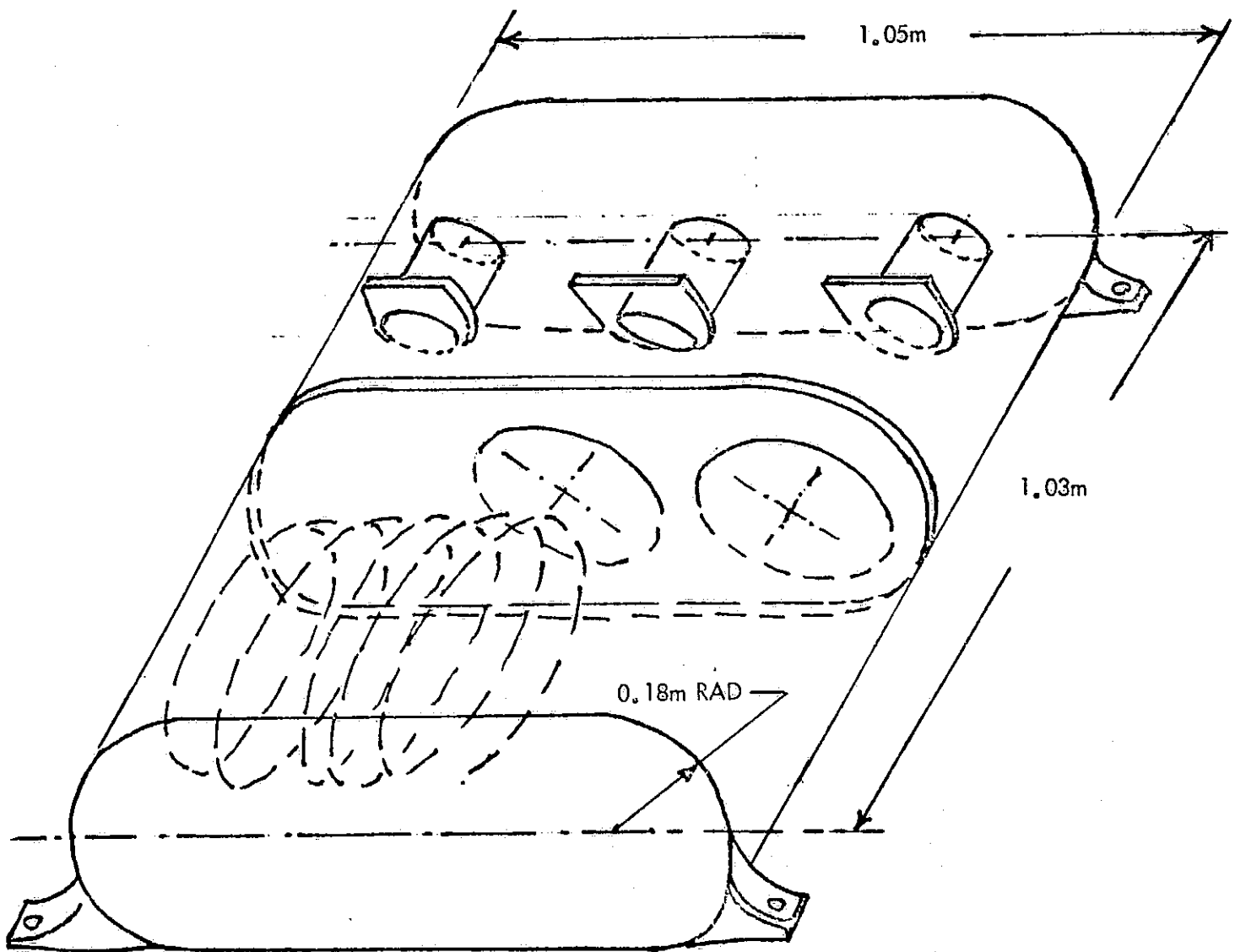


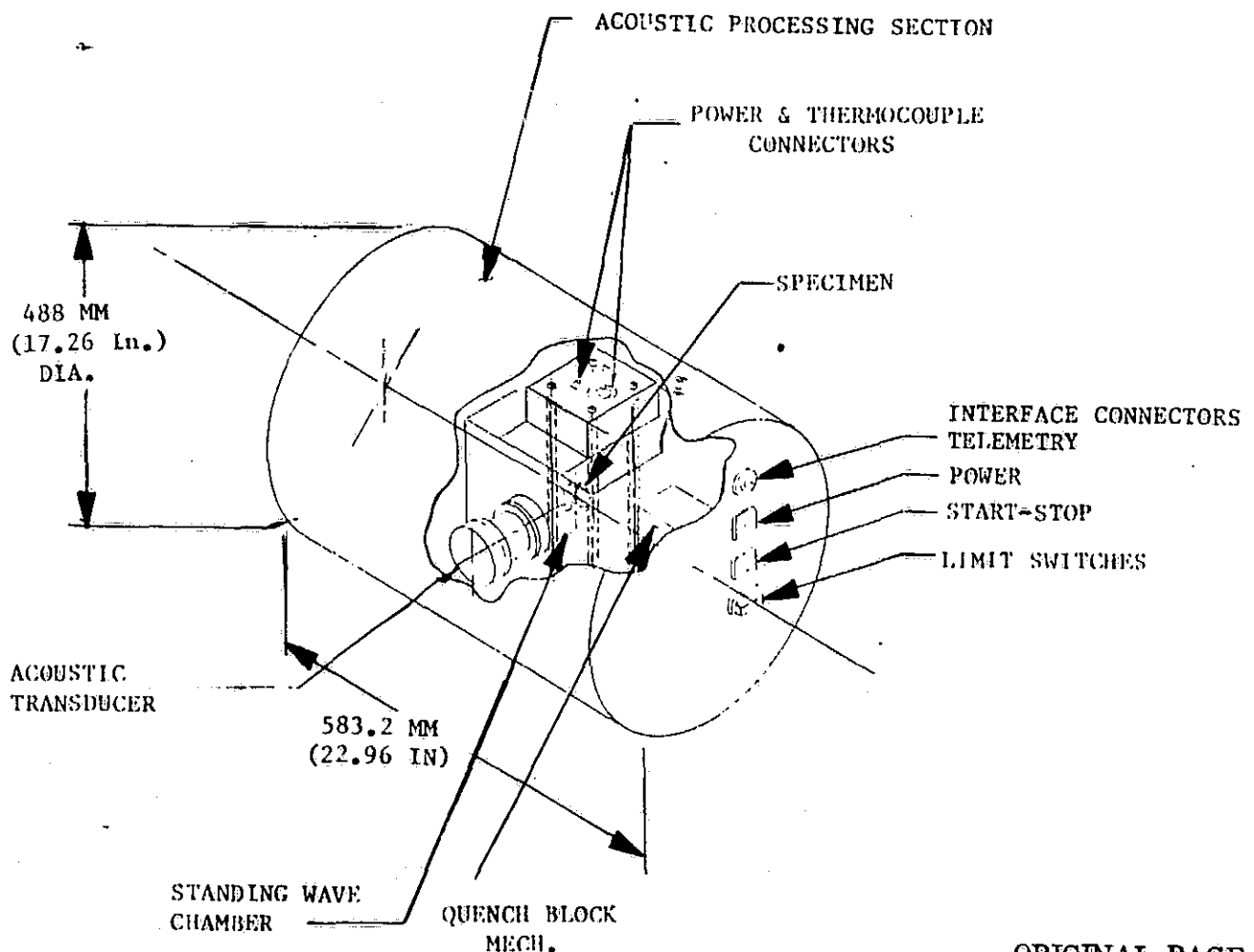
Figure 2-4. Electromagnetic Containerless Processing Facility -
Space Processing



The purpose of this facility is to produce ultra-high purity materials by use of ultra-high vacuum (wake effect), reduced hydrostatic pressure head, containerless processing, and reduced convection, buoyancy, and sedimentation. Three specimens corresponding to the three experiments (S9A, S9B, S21) will be installed in the chambers.

Acoustic Levitation Positioning Melt Facility

This facility is illustrated in Figure 2-5. A silica probe (or string) will be used to maintain the position of the sample in the oven cavity. The vitreous carbon sleeve prevents migration of the melt along the probe in a zero-gravity environment. This type of approach has been effective even in current ground-based research.



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Figure 2-5. Acoustic Containerless Processing Facility (Modified SPAR) - Space Processing



Alternate methods of insertion and cooling will be investigated. In the first alternate, a chuck holding the probe/sample will move to introduce the sample into the hot furnace cavity and remove it for cooling. A movable counterweight will be provided to maintain the center of gravity of the package. In the second alternate, the probe/sample will originate in the heater cavity and sustain pre-heat temperatures during lift-off and ascent. At the start of zero-g, the heater will be increased to melt temperature and the sample will be cooled in place. Techniques for achieving rapid cooling in place will be investigated. Counterweight compensation for moving parts will be considered, but for lower magnitudes than for the first alternate.

The two experiments in this facility are the melting of blanks for fiber optics (CG5) and the processing of chalcogenide glasses (CG7).

CG5 Containerless Melting of Blanks for Fiber Optics

The experiments proposed herein take advantage of low gravity and space vacuum to produce glass melt "free" from contamination from water and reaction products from a crucible, and which are free of density fluctuations due to gravitational effects and convection current. Several end uses of glasses produced in this way are possible. Specific experiments relate to fibers for optical communications and the production of "standard" glasses.

CG7 Space Processing of Chalcogenide Glasses

The unique environment of space consisting of weightless, containerless and vacuum will be exploited for fabricating a non-oxide chalcogenide glass such as $\text{Ge}_{28}\text{Sb}_{12}\text{Se}_{60}$ for use as a laser window material. The experiment will consist of mixing the raw materials, melting the mixture, quenching and annealing of the glass. This experiment's objectives are:

- . Generate larger sample sized than obtainable on earth
- . Atmospheric control from oxidizing in order to reduce stoichiometry control
- . Temp. capability to 2200 C to cover a broad range of oxide candidates
- . Clean and containerless environment for melting glass; i.e., to eliminate heterogeneous nucleation sites.

Multipurpose Furnace/Crystal Growth Melt Facility

This facility is used to heat material samples and the starting material inside an ampoule by radiant heat. Three distinct isothermal heating zones are used to achieve a linear temperature gradient. Provisions for insertion and withdrawal of samples are included. The facility is illustrated in Figure 2-6. The three experiments in this facility are the preparation of epitaxial films (54), crystal growth of material (57), and measurement of crystal growth characteristics (S14).

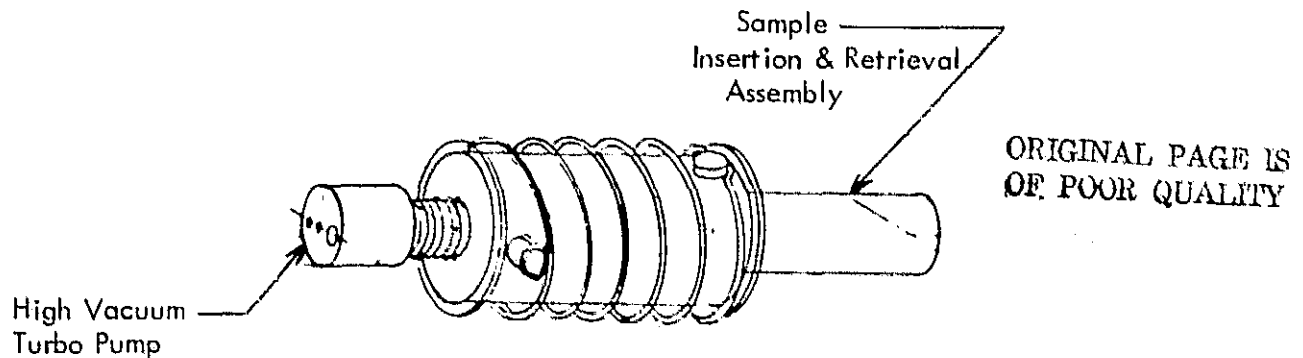


Figure 2-6. Multipurpose Furnace - Space Processing

S4-Preparation of High Point Defect Density Epitaxial Films

The objective of this experiment is to prepare semiconductor crystals with very high defect densities arising from the interaction of essentially inert gas atoms, under conditions approximating free fall, with a selected, active melt. A suitable material with sufficient activity, eg., potassium (K), is heated to the melting point. The temperature is then dropped and an inert gas is passed through the vapor which deposits on a suitable substrate. The convective flow process, which supplies the additional material, could help to make a new alloy, i.e., a semiconductor compound.

S7-Crystal Growth or Solidification of Material

Epitaxial films from molten solutions under conditions approximating free fall ($\sim 10^{-4}g$) will be produced by this experiment. The experiment is completely enclosed in a sealed cartridge, which contains a candidate material (e.g., indium arsenide, gallium arsenide, garnets, ferrites). The material will be used as a melt in an isothermal furnace with a mechanism that automatically inserts a crystal seed. The candidate material is heated isothermally to the melting point. The temperature is then reduced and the seed crystal introduced automatically. The temperature is reduced just enough from 800 C to permit the melt to crystallize a thin film on the seed.

S14-Crystal Growth by Chemical Vapor Transport

A quantitative measurement of micro-gravity effects on mass transfer rates, on crystal morphology or growth rates of individual crystal faces, and on structural and chemical microhomogeneity of single crystals will be conducted with this experiment.



The transport experiments are performed in the multipurpose furnace which can accommodate four individual transport ampoules enclosed in separate metal containers. The transport process is initiated with a halogen or a halide. The material sample and the starting material, are loaded and sealed in the ampoules on the ground. Source temperatures of 600 C to 800 C are used for vaporization. Condensation occurs on 500 C to 700 C surfaces, respectively. The temperature gradients should be approximately linear. The material sample and starting material react to form a gaseous species which migrates (diffuses) to the condenser where a reverse reaction occurs to produce single crystals (after 10 to 30 hours).

Float Zone Refining/Crystal Growth Facility

This facility (Figure 2-7) will provide the capability to conduct float zone refining of silicon (S6) and grow quiescent melt (S16) and aluminum antimony crystals (S25). The general objective is to provide space-grown samples for comparison with earth-grown samples. The potential for larger crystals and the influence of Marangoni thermocapillary connection without the perturbation of buoyancy driven material connection are principle reasons for this set of float zone refining experiments.

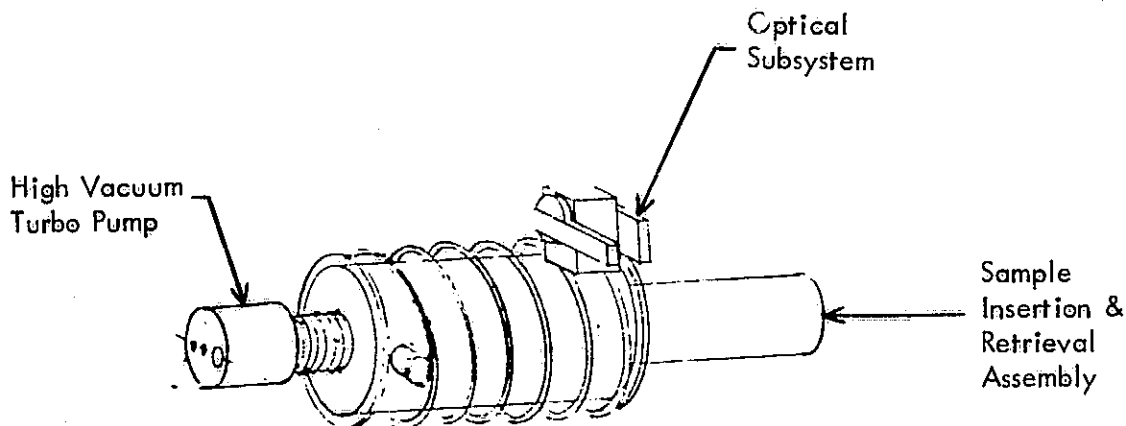


Figure 2-7. Float Zone Refiner/Crystal Growth Furnace -
Space Processing



All of the objectives can be met with four crystals mounted in one index magazine of the General Electric (G.E.) Modular Processing Facility and processed in one core assembly. The Float Zone Refining/Crystal Growth module is inserted into the Modular Processing Facility chamber, and receives support functions through interfaces provided by the chamber. These include process control, pressurization, evacuation, etc.

Equipment and control are provided for specimen rotation and linear positioning, seed crystal rotation and linear positioning, traversing of the chill block and the furnace, temperature control, etc., as well as direct observation by TV and film (camera) of the actual crystal growth interface. To minimize variations in the characteristics and quality of polysilicon starting material, a single rod of approximately 48 cm length will be obtained for each of the four space processing experiments. Each polysilicon rod will be divided into two ingots; one to be prepared and supplied for processing in the high vacuum (10^{-10} Torr) and low gravity ($10^{-4}g$) space environment and the other to be retained at Rockwell for an identical experiment, but performed in a terrestrial environment. The difference in the experimental results for the two environments will thus indicate the effects of float zone processing of silicon in space.

S6 - Float Zone Melting of Silicon

Specific objectives of the silicon melt experiment include the following:

- . Purification of silicon crystals in a high vacuum, low-containment, low-g space environment.
- . Investigation of effects on the segregation coefficient of residual impurities (viz, Boron) in silicon by a single vacuum pass.
- . Comparison of macroscopic/microscopic distribution of phosphorous and boron in intrinsically doped silicon.
- . Investigation of influence of growth rate on homogeneity and structure in intrinsic silicon crystals.
- . Characterization of crystallographic structure in 'undoped' silicon grown in low-g space.
- . Comparison of impurity distribution, structure and segregation coefficient between silicon doped with Indium to a level of 2×10^{12} atoms/cm³. Precipitation dependence on concentrations.
- . Comparison of silicon crystal growth with an Indium concentration greater than 10^{18} atoms/cm³. Also, investigate the solubility limit in homogeneous material and observe the onset of Indium precipitation.



S16 - Crystal Growth from Quiescent Melt

Crystals of simple compounds and solid solutions will be grown under conditions that lead to substantial differences between crystal and melt composition. Surface tension and convection effects will be observed.

The specific objective of the experiment is to grow single crystals (Germanium Telluride (GeTe), Stannous Telluride (SnTe), and Lead Telluride (PbTe) of simple compounds, and of solid solutions, under conditions that lead to substantial differences between the single crystal and melt composition.

S25 - Containerless Zone-Growth Aluminum Antimony (AlSb) Crystal

Objectives are essentially the ones stated in experiment S6, i.e., the specific objective is to zone refine Homogeneous Polycrystalline AlSb. On Earth, the large difference in density between the two constituents and their reactivity to containers are the principal causes for the difficulties in growing single crystals without twins or other defects; therefore, containerless processing is needed.

PAYLOAD CONFIGURATION

In order to establish realistic estimates of Level IV installation and checkout requirements, a flight configuration of the Space Processing payload was synthesized. All end items were identified and specific locations for these items were established.

Component Layouts

The configuration and end item callouts are shown in Figure 2-8. The only Spacelab interfacing equipment illustrated is the RAU and EPDB. However, coldplates, interconnect stations (I/C) and connector brackets are also included in the configuration. It was assumed that installation of all Spacelab interfacing equipment (including interconnections between coldplates) is performed during staging activities at KSC. All other end items are installed as part of the level IV activity. It should be noted that the freon pump and heat exchangers indicated in the figure are experiment unique equipment (for the furnace quench systems) and are in addition to the heat exchangers/coldplates and freon pump provided as part of Spacelab interfacing equipment.

In addition to the equipment mounted on the pallet, controls and displays are also required and are mounted in the Orbiter Aft Flight Deck (AFD). A typical control and display panel indicating the payload requirements is illustrated in Figure 2-9. For the purpose of autonomy, a single rack was configured. The upper right section is for dedicated and hardwire controls of the melt facilities. The lower half contains the strip chart recorder. A Spacelab CDMS CRT and keyboard are indicated in the upper left section for reference only. The CRT and keyboard were chosen to reduce the total quantity of hardwires between the AFD to the payload. The CDMS CRT keyboard need not be dedicated to the payload but can be used to support the payload.

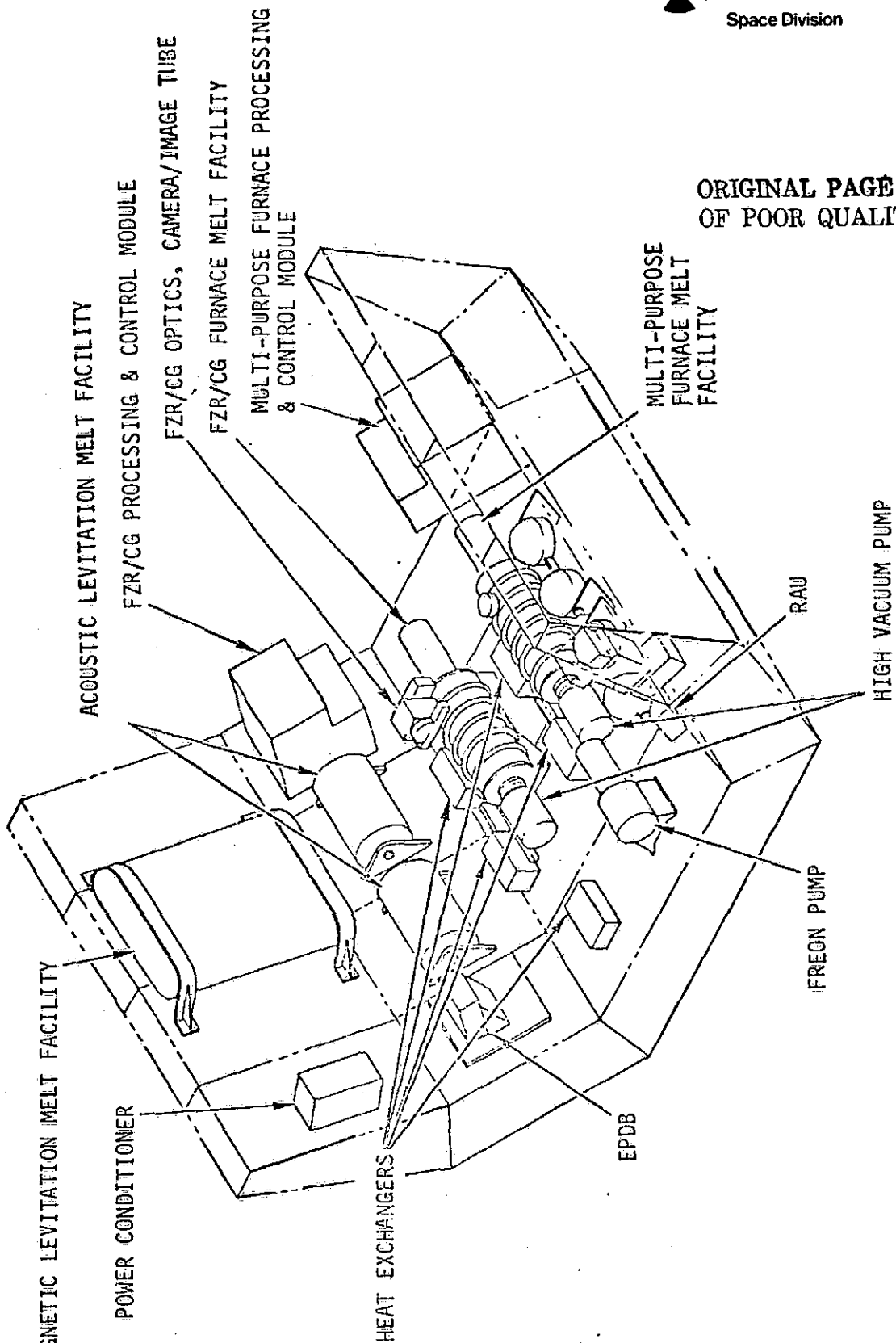


Figure 2-8. Space Processing Payload Component Layout



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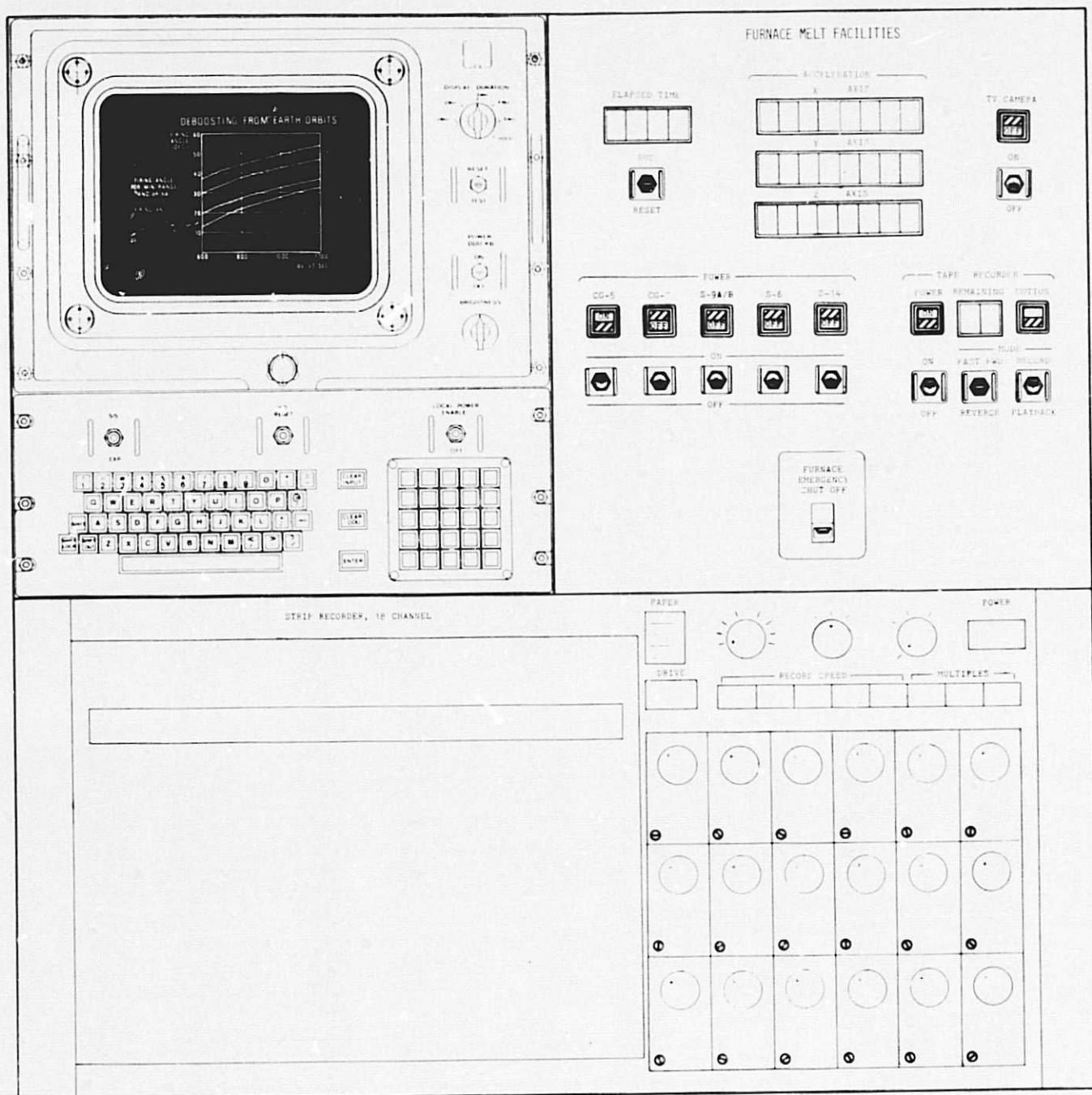


Figure 2-9. AFD Controls and Displays

2-14

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Payload Cabling

A significant effort during Level IV activities is the installation and verification of interconnections between end items. Functional wiring diagrams were developed to illustrate these interconnections. Figure 2-10 indicates the composite interconnections between end items (EI) for the Space Processing payload. Spacelab subsystem connections are in addition to those shown in the figure.

These end item interconnections were synthesized from the functional requirements identified for each experiment/facility, which are detailed in the GPR EDP's in the appendix. The number of wires were estimated for each interconnection. Connectors were estimated based upon the following guidelines:

- a) A maximum of 40 wires will be permitted in each connector
- b) Signal and power functions will be separated
- c) Functions from one end item to multiple facilities will be separated

Routing of the wires between end items was established and cable lists were developed. The cable groupings also reflected separation of signal and power functions. The cable list and approximate length of each cable is presented in Table 2-2.

Payload Fluid Lines

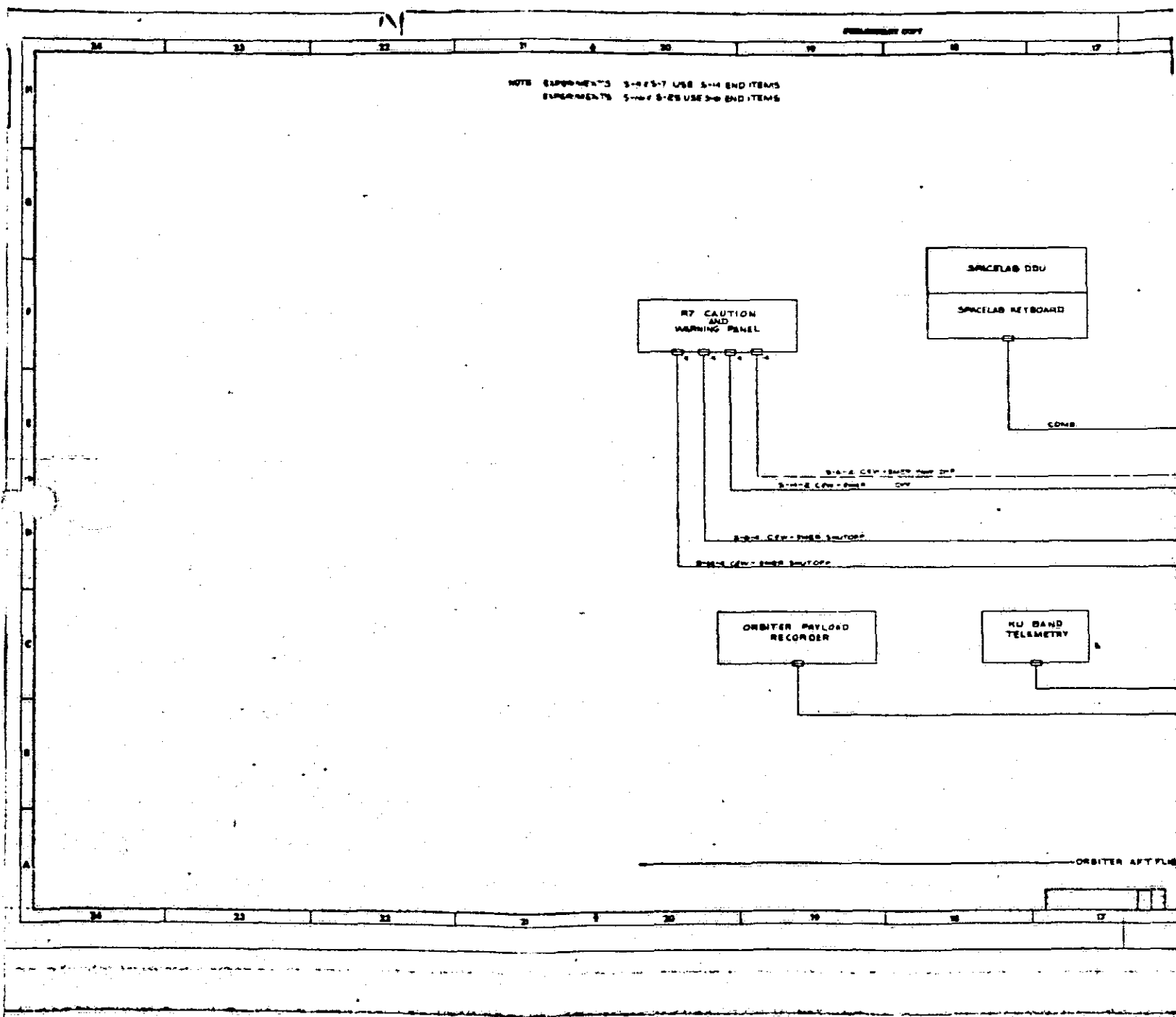
The operating temperatures and modes of the facilities of the Space Processing payload result in an experiment unique coolant system. Coolant loop interconnection between experiment end items is a significant task. A layout of the coolant loop comparable to the cable diagram was developed. A summary of the coolant loop routing and connections is presented in Figure 2-11.

Summary

Space Processing level IV ground processing installation and checkout activities are detailed in Volume II. These estimates are based upon the layout, end item descriptions, and cable and fluid interconnections defined in this section. Checkout activities encompass both the functional requirements identified in the GPR EDP's and the verification of the electrical and fluid connections established during experiment equipment installation.

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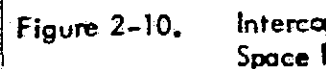


FOLDOUT FRAME /

The diagram illustrates the electrical architecture of the Orbiter APT Flight Deck. Key components and their connections include:

- C/D Panel (3-0-1/3-0-1)**: Connected to the CDS Unit and various SC units.
- CDS Unit**: Contains a Micro (Micro) section and a Display/Control section. It is connected to the C/D Panel and the APD FDS.
- APD FDS**: Connected to the CDS Unit and the Orbiter APT Flight Deck.
- SC Units (Signal Conditioners)**: A series of units (SC-1 through SC-10) that interface between the C/D Panel, CDS Unit, and the Orbiter APT Flight Deck.
- Orbiter APT Flight Deck**: The primary interface for the pilot, connected to the SC units and the APD FDS.
- Orbiter APT Flight Deck (Secondary)**: A secondary interface unit connected to the SC units and the APD FDS.

The diagram shows a complex network of lines representing electrical connections between these components, with labels indicating specific signal paths and component identifiers.



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FRAME 3



Table 2-2. Cable List for Space Processing Payload

FACILITY #/EXP'T NO.	CABLE NO.	FROM	TO	APPROX LENGTH (FT)
FACIL. #4/5-6,16,25	PC-1 (AC)	E.I. 5	EPDB ON PALLET	8
	PC-2 (DC)	E.I. 2	EPDB ON PALLET	3.3
	PC-3 (AC)	E.I. 2	EPDB ON PALLET	3.3
	PC-4 (DC)	E.I. 2	E.I. 3	7
	PC-5 (DC)	E.I. 2	E.I. 4a	5
	PC-6 (AC)	E.I. 2	E.I. 3	6
	SC-1	E.I. 2	E.I. 5	10.65
	SC-2	E.I. 3	E.I. 5	7.54
	SC-3	E.I. 5	RAU ON PALLET	17.75
	SC-4	E.I. 4a	E.I. 5	13
	SC-5	E.I. 4b	E.I. 5	13
	SC-6	E.I. 3	RAU ON PALLET	5.16
	SC-7	E.I. 4a	RAU ON PALLET	8.53
	SC-15a	E.I. 3	CB42	10
	SC-15b	CB42	X _o 576 BULKHEAD	14
	SC-15c	X _o 576 BLKHD	E.I. 1 (C/D PANEL)	16
	SC-17a	E.I. 4a	CB42	10
	SC-17b	CB42	X _o 576 BULKHEAD	14
	SC-17c	X _o 576 BLKHD	R7 (C&W PANEL)	18
	SC-23a	E.I. 2	CB42	10
	SC-23b	CB42	X _o 576 BULKHEAD	14
	SC-23c	X _o 576 BLKHD	R7 (C&W PANEL)	18
FACIL. #3/514,7,4	PC-7	E.I. 2	E.I. 3	5
	PC-8 (DC)	E.I. 2	E.I. 4a	14.1
	PC-9 (AC)	E.I. 2	E.I. 3	5
	PC-10 (DC)	E.I. 5	EPDB ON PALLET	14.1
	SC-8	E.I. 2	E.I. 5	16.11
	SC-9	E.I. 3	E.I. 5	18.13
	SC-10	E.I. 5	RAU ON PALLET	6.56
	SC-11	E.I. 4a	E.I. 5	8.53
	SC-12	E.I. 4b	E.I. 5	13
	SC-13	E.I. 3	RAU ON PALLET	13
	SC-14	E.I. 4a	RAU ON PALLET	5.16
	SC-16a	E.I. 3	CB42	8.53
	SC-16b	CB42	X _o 576 BULKHEAD	14
	SC-16c	X _o 576 BLKHD	E.I. 1 (C/D PANEL)	16
	SC-18a	E.I. 4a	CB42	10
	SC-18b	CB42	X _o 576 BULKHEAD	14
	SC-18c	X _o 576 BLKHD	R7 (C&W PANEL)	18
	SC-24a	E.I. 2	CB42	9
	SC-24b	CB42	X _o 576 BULKHEAD	14
	SC-24c	X _o 576 BLKHD	R7 (C&W PANEL)	18
FACIL. #2/CG-5	PD-14 (DC)	E.I. 1	AFT PDB	15
	PC-11 (DC)	E.I. 1	EPDB ON PALLET	5
	SC-19a	E.I. 1	CB42	10
	SC-19b	CB42	X _o 576 BULKHEAD	14
	SC-19c	X _o 576 BLKHD	S-6 & S-14 E.I. 1 (C/D PNL)	16
FACIL. #2/CG-7	SC-20	E.I. 1	RAU ON PALLET	8
	PC-12 (DC)	E.I. 1	EPDB ON PALLET	5
	SC-21a	E.I. 1	CB42	14
	SC-21b	CB42	X _o 576 BULKHEAD	14
FACIL. #1/5-9a, 5-9b & 5-21	SC-21c	X _o 576 BLKHD	S-6 & S-14 E.I. 1 (C/D PNL)	16
	PC-13 (DC)	E.I. 1	EPDB ON PALLET	5
	SC-25a	E.I. 1	CB42	14
	SC-25b	CB42	X _o 576 BULKHEAD	14
	SC-25c	X _o 576 BLKHD	S-6 & S-14 E.I. 1 (C/D PNL)	16
	SC-26	E.I. 1	RAU ON PALLET	8

LEGEND:

SC = Signal Cable
PC = Power Cable
EI = End Item (of an experiment as listed in the GPREDP)
CB = Canister Bracket



FREON LINES

- F1 - JUNCTION A TO HEAT EXCHANGER (HE)
- F2 - MPF FURNACE TO JUNCTION A
- F3 - HE TO DEDICATED FREON PUMP (DPP)
- F4 - DPP TO JUNCTION B
- F5 - JUNCTION B TO MPF-3
- F6 - MPF LIQUID/GAS HEAT EXCHNGR (LGHE) TO JUNCTION A
- F7 - MPF-3 TO JUNCTION C
- F8 - JUNCTION A TO JUNCTION D
- F9 - LGHE (FZR-4A) TO JUNCTION D
- F10 - FZR TO JUNCTION D
- F11 - FZR (FZR-3) TO LGHE (FZR-4A)
- F12 - JUNCTION B TO FZR-3

COOLANT LINES

- C1 - LGHE (MPF-4A) TO MPF-3
- C2 - MPF TO LGHE (MPF-4A)
- C3 - LGHE (FZR-4A) TO FZR-3
- C4 - FZR TO LGHE (FZR-4A)

GAS LINES

- G1 - HELIUM TANK VALVE TO JUNCTION F
- G2 - JUNCTION F TO LGHE (MPF-4A)
- G3 - LGHE TO MPF-3
- G4 - MPF TO LGHE-4A
- G5 - MPF VALVE TO JUNCTION C
- G6 - MPF TO JUNCTION C
- G7 - JUNCTION C TO SPACE VENT
- G8 - ARGON TANK VALVE TO FZR-3
- G9 - OXYGEN TANK VALVE TO FZR-3
- G10 - JUNCTION F TO LGHE (FZR-4A)
- G11 - LGHE TO FZR-3
- G12 - FZR-3 TO LGHE (FZR-4A)
- G13 - FZR-3 VALVE TO JUNCTION E
- G14 - FZR-3 TO JUNCTION E
- G15 - JUNCTION E TO SPACE VENT

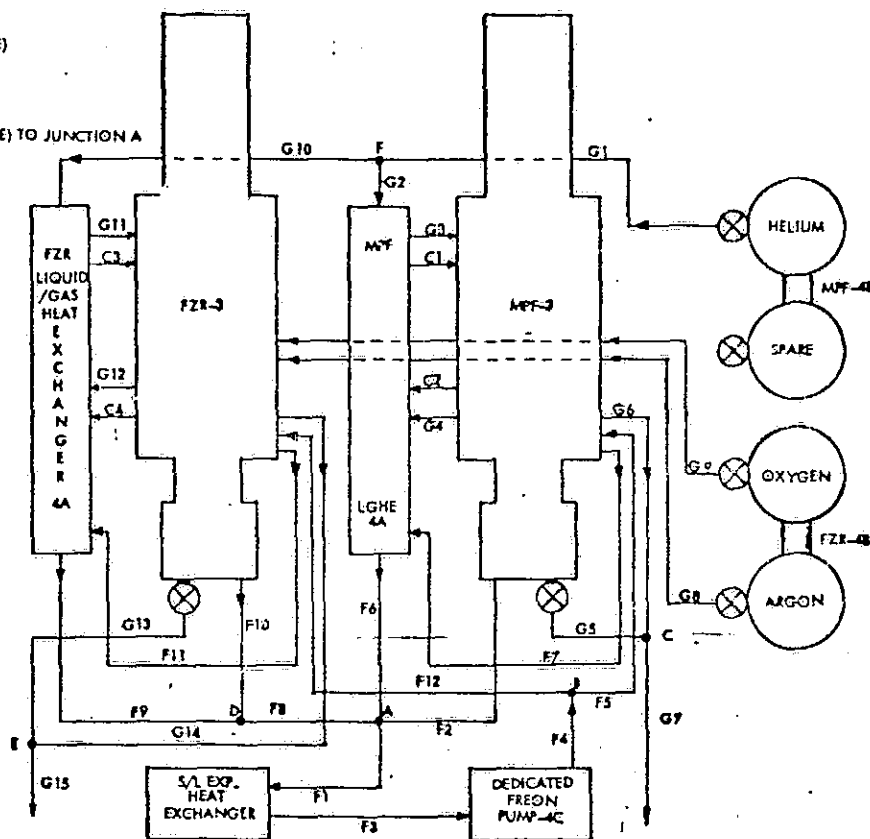


Figure 2-11. Gas and Liquid Pipeline Interfaces
Space Processing Payload



3.0 COMBINED ASTRONOMY PAYLOAD

INTRODUCTION

A Combined Astronomy payload was synthesized for this study that would be representative of the planned Astrophysics investigations and encompass typical payload configurations. The synthesized payload is illustrated in Figure 3-1. The four major experiments included in this payload and their sponsoring lead center are listed in Table 3-1.

Table 3-1. Combined Astronomy Experiments

Experiment	Center
Far Ultraviolet Schmidt Camera/Spectrograph	Goddard Space Flight
Ultraviolet Photometer/Telescope	Goddard Space Flight
Medium Energy Gamma-Ray Detector	Goddard Space Flight
Shuttle Infrared Telescope Facility	Ames Research

The synthesized configuration includes five pallet segments and fine pointing systems for small and large sensors. A Small Instrument Pointing System (SIPS) is mounted on the lead pallet for precision pointing of the Schmidt camera and UV Photometer sensors that are mounted in thermal canisters (forward complement). The Instrument Pointing System (IPS) is mounted on the second pallet and attached to the Shuttle Infrared Telescope Facility (SIRTF) for precision pointing during orbital operation (mid complement). The gamma ray detector is hard mounted to the last pallet (aft complement). The one-one-two-one pallet segment configuration of this payload was selected to maximize the viewing angles of the sensors and minimize the potential interference between instruments and between instruments and Orbiter structure.

This particular five pallet segment configuration is not included in Orbiter-Spacelab interface control documents. However, mass and center-of-mass characteristics of this configuration were assessed and were within both Orbiter and Spacelab design constraints. The total payload weight at liftoff is 32,880 pounds (14,945 Kg) and at landing 31,925 pounds (14,511 Kg). These weights are well within the launch and landing Space Transportation System (STS) constraints. The center-of-mass of this payload moves only a fraction of an inch from $X_{0.958.2}$ to approximately $X_{0.957.8}$ due to the expulsion and loss of fluids. The relative position of the center of mass (in Orbiter station notation) is shown in Figure 3-2.

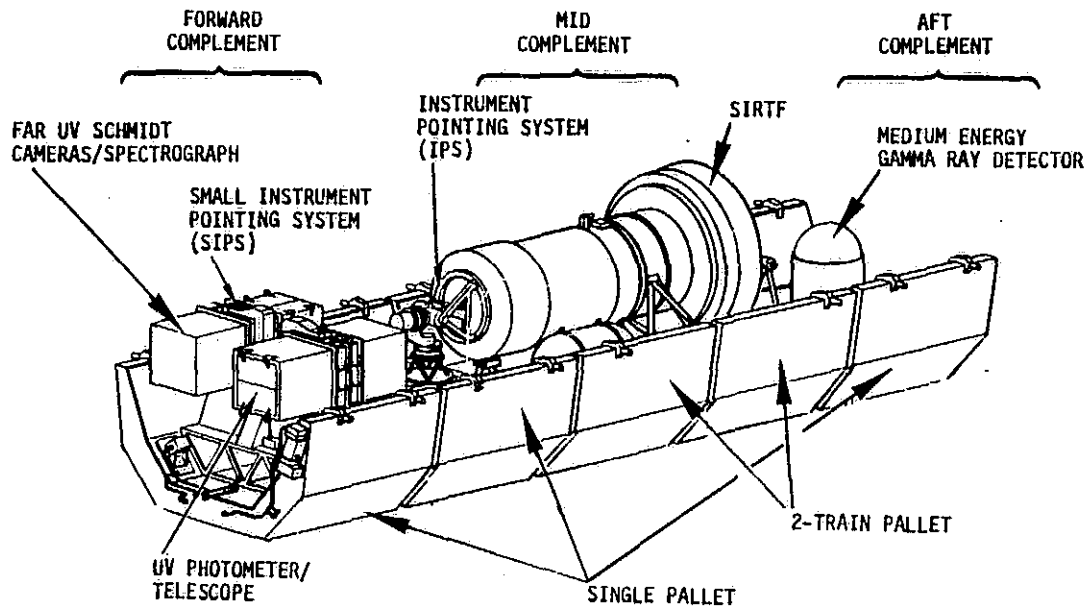


Figure 3-1. Combined Astronomy Payload Configuration

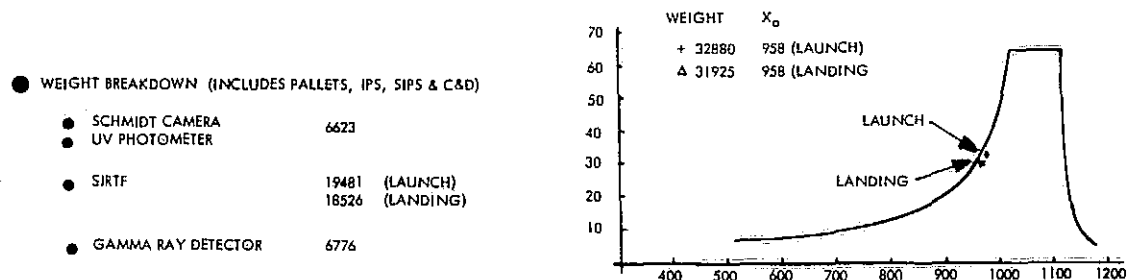


Figure 3-2. Combined Astronomy Payload Center of Mass Location

EXPERIMENT COMPLEMENT

A synopsis of the objectives and characteristics of the experiment of the combined astronomy payload is presented subsequently. Detailed descriptions of these experiments are contained in the GPR EDP's in Appendix B.

Far Ultraviolet Schmidt Camera/Spectrograph

The objectives of this experiment are to obtain far-ultraviolet imagery and intermediate-resolution spectra in the 950-1600 and 1250-2000 Å wavelength ranges, of stars and stellar objects, emission and reflection nebulosities, planetary nebulae, relatively nearby external galaxies and the brighter Seyfert galaxies, and quasars. The stellar spectra will also provide information on the distributions of interstellar dust, atomic hydrogen, molecular hydrogen, and (for the more distant and/or reddened stars) atomic oxygen, nitrogen, and carbon. Particular emphasis is placed on obtaining accurate absolute and relative far-UV flux distributions for the observed objects. In addition, far-ultraviolet imagery and spectra of any targets of opportunity such as bright comets will also be obtained.



The primary instrument for this experiment is a far-ultraviolet electrographic Schmidt camera/spectrograph, which was originally designed as a sounding rocket experiment and currently in use as such. The instrumentation is based on an electrographic Schmidt camera, which is similar to but larger and more powerful than the camera utilized in several sounding rocket flights, the Apollo 16 lunar mission, and the Skylab 4 mission.

Figure 3-3 is a diagram of one of the two instrument packages which would be used for a Spacelab mission. The package includes a 15-cm aperture and an $f/2$ Schmidt optical system. The field of view is 11 degrees in diameter (circular) and will produce images 65 mm in diameter on 70 mm film. The limiting resolution is roughly 20 arc seconds, and the spectral resolution with objective grating is $1.5 \text{ \AA}$ with a 600 line/mm grating, or $0.75 \text{ \AA}$ with a 1200 line/mm grating.

The spectral response of the instrument is determined by the combination of photocathode quantum efficiency, mirror coating reflectance, and corrector plate transmission versus wavelength. For spectrography in the wavelength range below the transmission limit of LiF ($1050 \text{ \AA}$), an annular aperture is used in place of a corrector plate. The aperture increases the effective focal ratio of the camera from $f/2$ to $f/6$, which reduces the spherical aberration sufficiently that a spectral resolution of better than $2 \text{ \AA}$ is obtainable. Some loss in sensitivity at longer wavelengths occurs with the aperture.

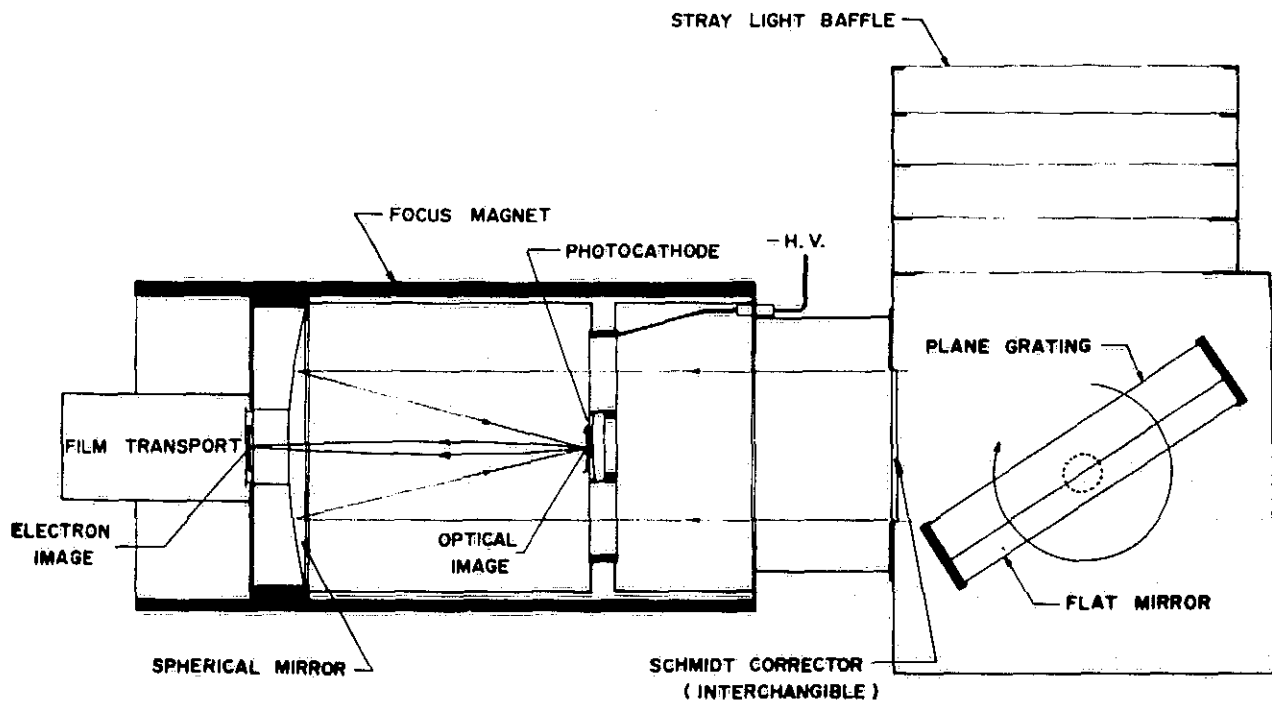


Figure 3-3. Schmidt Camera/Spectrometer Diagram

The experiment equipment is mounted into one of the SIPS canisters (Figure 3-4). The canister is specially designed to allow the equipment to view out the top (not the normal end position) positioned doors. The SIPS raises the canister above the Orbiter mold line and points very precisely at preselected survey and opportunity and targets. Environmental conditioning is provided by the SIPS canister. Telemetry data is coupled through a Spacelab RAU mounted in the canister. Scientific data is also recorded on photographic film mounted onto the backs of each of the cameras.

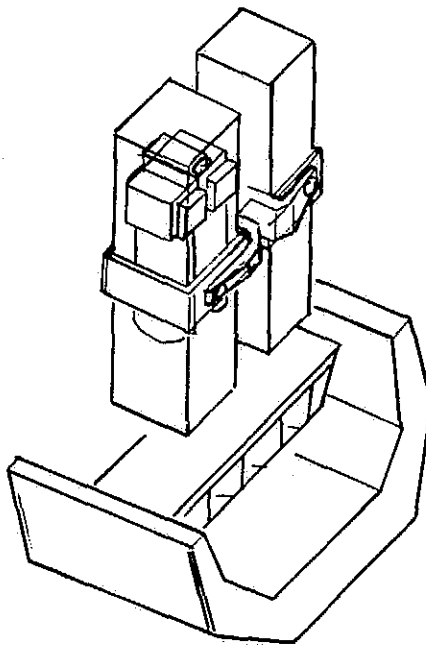


Figure 3-4. Far UV Schmidt Camera/Spectrograph Installation

Ultraviolet Photometer/Telescope

The UV photometer is used to establish a net of about 40 early-type stars distributed over the sky with accurately determined relative photometry over the spectral interval 925-3400 Å; and to establish the absolute energy calibration for these stars. In addition, the instrument will be used to conduct spectral surveys in selected UV wave lengths and obtain flux distribution and energy spectrum in the UV region. The UV photometer will obtain linear and circular polarization data about each of the targets.



The UV photometer (Figure 3-5) includes a spectrograph feeding seven detectors with sensitivities between 900 Å and 1700 Å (each with about 50 Å bandwidths) and four individual filter photometers sensitive to radiation from about 1900 Å to 3400 Å with band-passes ranging from 50 Å to about 200 Å.

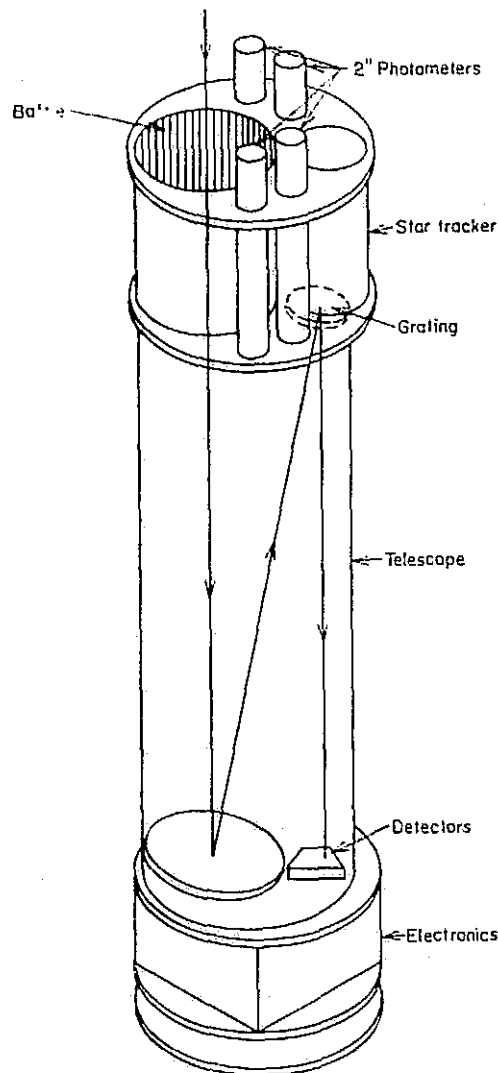


Figure 3-5. UV Photometer/Telescope Diagram



The spectrograph consists of an 8-inch spherical mirror ($\text{FOV} = 0.5$ degrees) which illuminates with a converging bundle of light, a 600 line/mm plane diffraction grating blazed at $1200 \text{ \AA}$. The resulting spectrum, with a dispersion of about $12 \text{ \AA/mm}$, is focussed on windowless channeltrons fixed in the focal plane; these detectors are operated in a pulse counting mode. The entire payload is evacuated before flight to minimize out-gassing problems.

The photometers are quartz refractors with layered MgF_2 -Al interference filters shaping the ultraviolet pass bands, and EMI 6256b photomultipliers operating.

The package consists of an objective-type grating spectrometer for the vacuum ultraviolet region and small photometers for specific wavelengths in the near ultraviolet.

The spectrometer (Monk-Gillieson type) uses a concave spherical mirror and a plane grating. The mirror is illuminated by light from the star with the field being limited by a slit baffle. The wavelengths observed are determined by the positioning of individual open cathode channeltron multipliers along the direction of dispersion in the focal surface. Because of the objective position of the grating in this instrument, the pointing accuracy necessary for good definition of the bandpasses wavelengths is ± 15 arc seconds.

The four small photometers are telescopes with quartz lenses and interference filters and use photomultipliers as detectors. The interference filters define bandpasses several hundred Angstroms wide in the middle ultraviolet. The pointing accuracy necessary for these instruments is ± 5 arc minutes.

The sensor is mounted in one of the standard SIPS canisters as shown in Figure 3-6. The canister provides the required environmental control and cleanliness during all phases of a mission; the SIPS also provides the necessary deployment beyond the Orbiter moldlines and accurately points the instrument.

All scientific and housekeeping data is processed within the photometer electronics. These data become part of the telemetry stream via a Spacelab RAU within the canister. A minimum of direct (hardline) controls are required to operate the experiment. The primary control interface is through the Spacelab CDMS CRT and keyboard.

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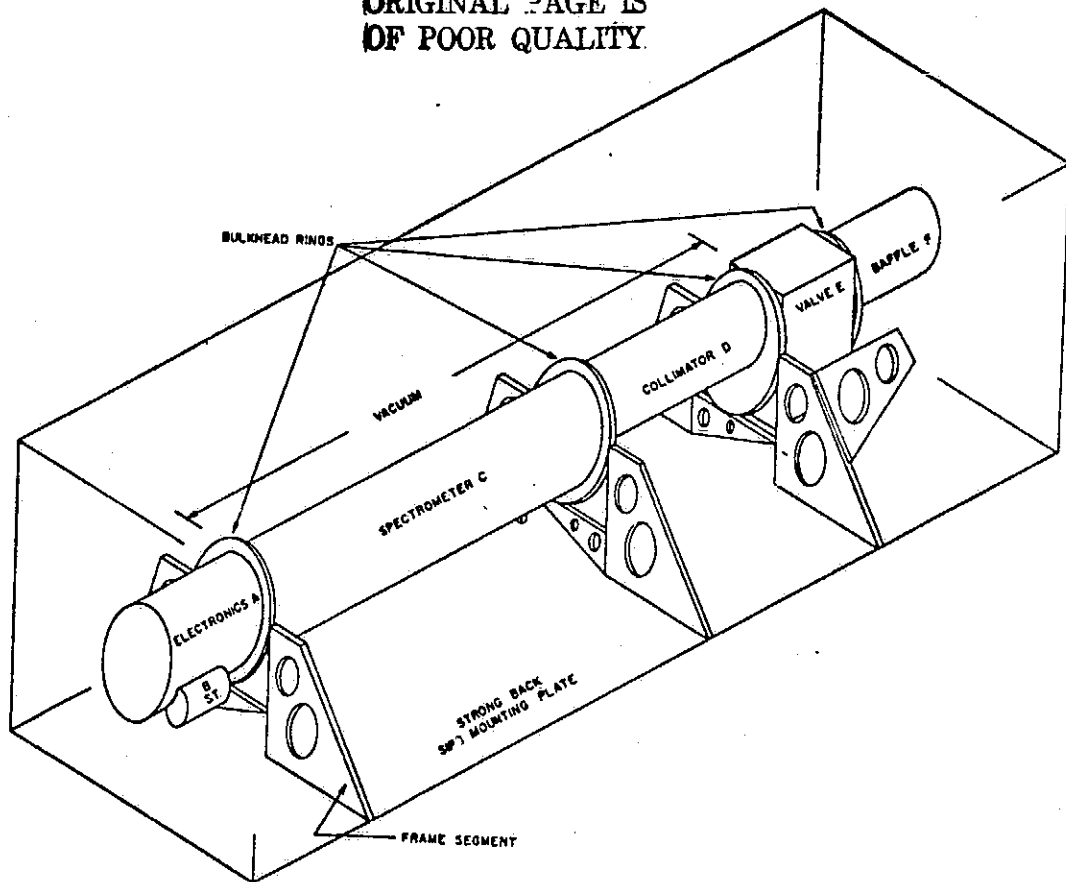


Figure 3-6. UV Photometer/Telescope Installation

Medium Energy Gamma Ray Telescope

The objective of this experiment is to study the spatial, spectral and temporal characteristics of medium energy, (i.e., 8 to 150 Mev) gamma radiation in earth orbit. This study will provide a better insight into the emission mechanisms associated with celestial phenomena, such as pulsars, supernovae, other galaxies, and, possible, discrete gamma-ray stars.

The experiment sensor (Figure 3-7) employs a stacked configuration pair of production plates, spark chamber assemblies and scintillation tile arrays placed above a total absorption shower cascade detector. The scintillator tiles are used for time-of-flight measurements and directional data. In addition, in order to discriminate between gamma ray photos and charged cosmic particles, the front end of the gamma ray telescope incorporates an anti-coincidence scintillation dome.

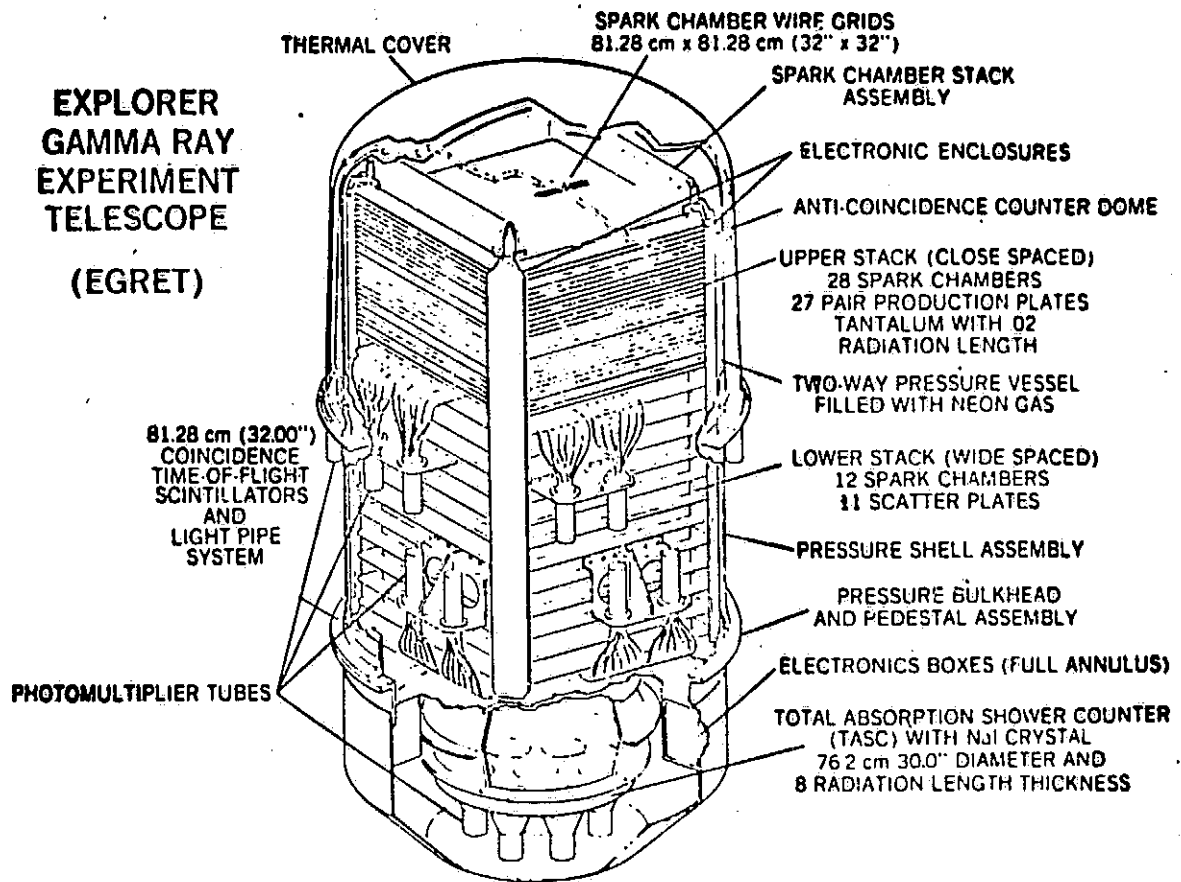
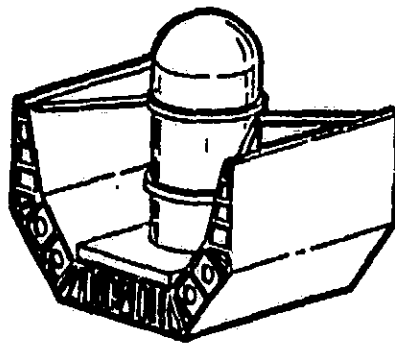


Figure 3-7. Medium Energy Gamma-Ray Detector - Cutaway



The gamma ray sensor mounts directly to the Spacelab pallet (Figure 3-8). The Orbiter provides any necessary pointing that may be required by the sensor; however, it normally operates as a passive payload element accepting any stimuli present in its field of view.



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Figure 3-8. Gamma-Ray Detector Installation Medium Energy

Shuttle Infrared Telescope Facility (SIRTF)

The overall mission objectives of this experiment are to determine the physical processes such as the nature and structure of stars, galactic nebulae, interstellar matter, galaxies and other sources of infrared radiation in the 1-1000 μm wavelength region, and also to make observations of line emission in comets and planets. Specific objectives are:

- (a) To obtain accurate total luminosities of all types of galactic and extra-galactic objects.
- (b) To perform an unbiased survey to understand what kind of infrared objects exist, detailed shape of the infrared flux distribution to obtain deviations from the smooth continua.
- (c) To determine line positions and profiles.
- (d) To obtain complex index of refraction and particle size of interstellar matter; to gather information on surfaces of planets, satellites, asteroids, and comet dust clouds.



- (e) To develop accurate continuum profiles for planets, stars, interstellar matter and the like; to obtain measurements of relative and absolute intensities of lines.
- (f) To obtain relative brightness measurements in selected infrared bands.

The illustration shown in Figure 3-9 depicts the SIRTf telescope only. The multiple instrument compartment or scientific instrument chamber, shown empty, provides a separate mechanical, thermal and electrical integration structure for up to six infrared astronomical instruments. Typical instruments include single-or-multiple detector radiometers or photometers, polarimeters, grating spectrometers, and interferometer spectrometers. A selector mirror near the focal plane of the SIRTf telescope directs the beam into one of the instruments. At the completion of a given observation, the same source can be observed by another instrument.

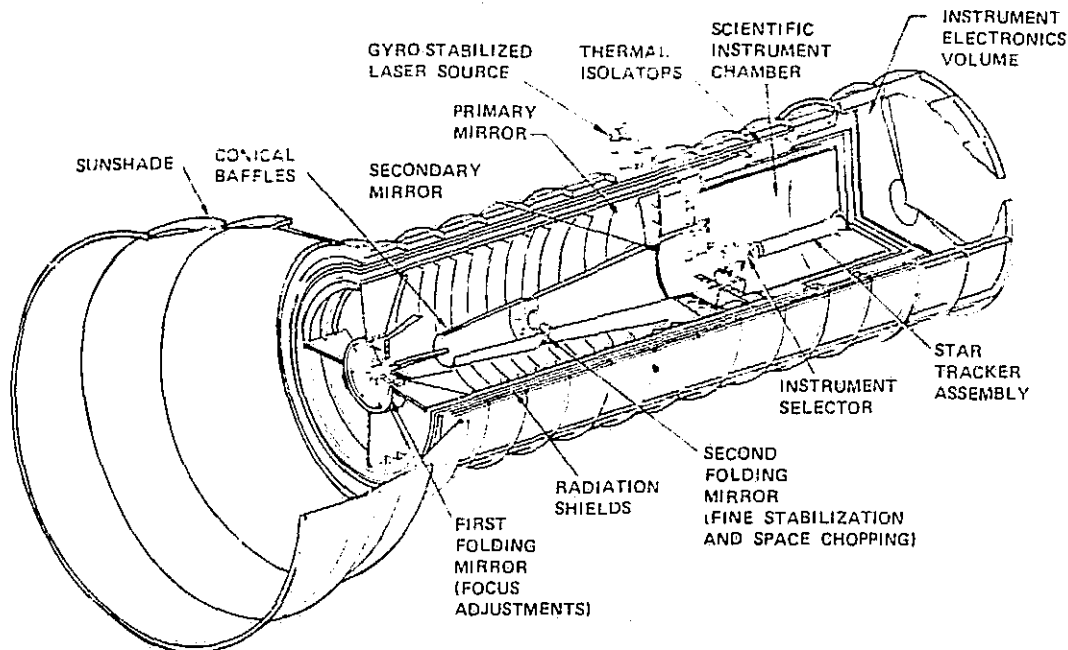


Figure 3-9. SIRTf Telescope - Cutaway

Subsystem Support and Implementation: The SIRTf consists of a 1.6-meter telescope, aperture cover, supercritical helium plumbing, telescope ballast, forward and aft trunnions, and a Spacelab instrument pointing system (IPS). These equipment items are mounted on a 2-train pallet system plus a single pallet (Figure 3-10). During launch and entry, the telescope is disengaged from the IPS and is secured by appropriate trunnions to the 2-train pallets. During operation, the telescope is attached to the IPS that is mounted on a third pallet segment. Except in the directly aft direction, the SIRTf is pivoted about a 60-degree half cone angle. In the aft direction, a limitation of 45.5 degrees from the axis (Z-X plane) is imposed to prevent undesirable reflections from the Orbiter rudder.

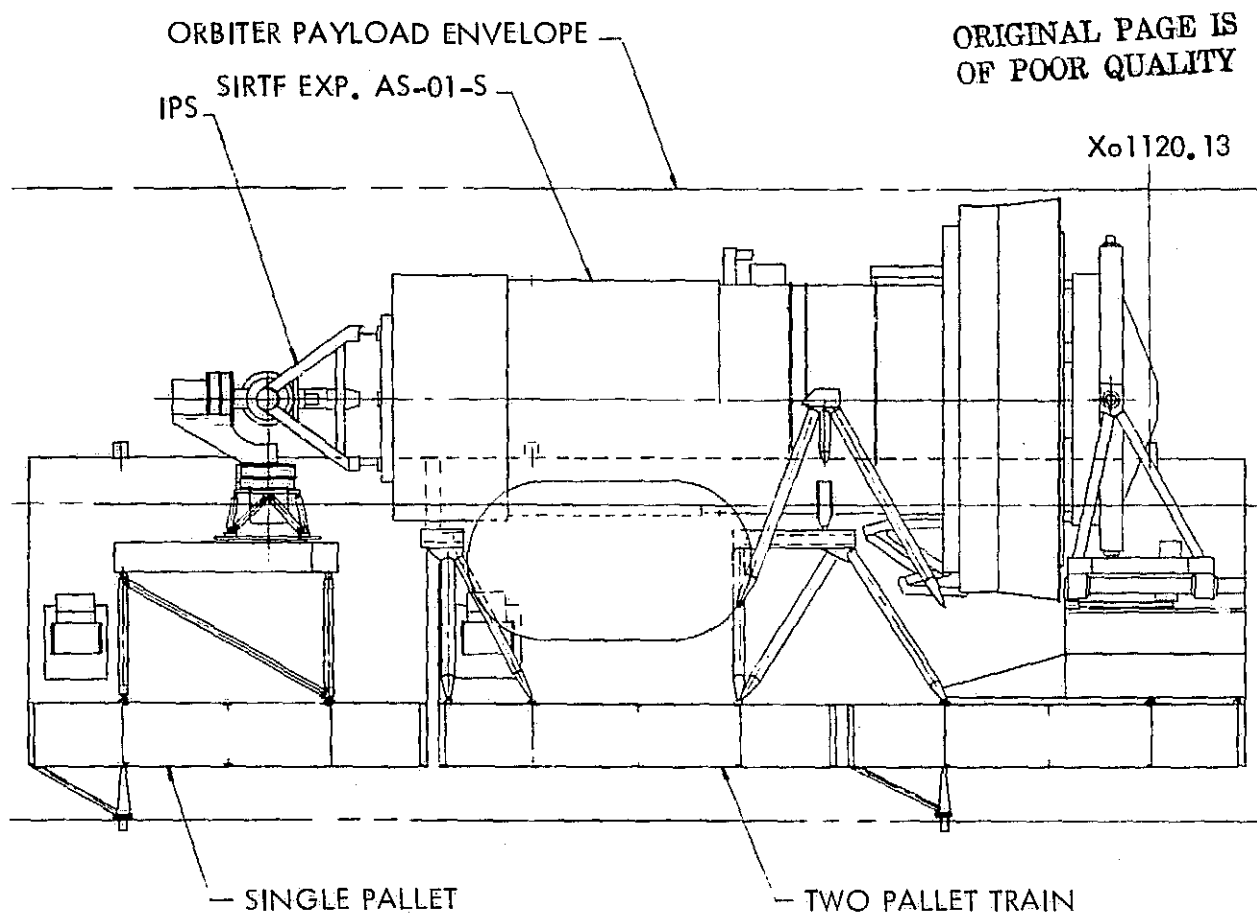


Figure 3-10. SIRTf Flight Configuration

The telescope is equipped with a retractable sun shield which reduces scattered infrared radiation into the telescope and heat loads on the cryogenic cooling system. During the launch and entry phases the sun shield is retracted allowing the telescope aperture cover to seal the telescope and to provide additional load carrying structure. The purpose of the seal is to provide light protection and to maintain a vacuum within the telescope to prevent contamination. Supercritical helium is used to cool the telescope and is stored in a cryogenic tank attached to the telescope.

Science data are digitized in the Multiple Instrument Compartment (MIC) and transmitted through Remote Acquisition Units (RAU) to the Spacelab CDMS for processing. The data is displayed at the payload specialist station and transmitted to ground.



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Space Division

Sensitivity of the SIRTf sensors to contamination, especially water vapor, requires that the water generated by the Orbiter fuel cells be stored during the mission and either dumped overboard prior to entry or at carefully-controlled intervals. An Orbiter payload kit consisting of storage tanks that are mounted in the lower aft portion of the cargo bay are used for this function.

PAYLOAD CONFIGURATION

The integrated combined astronomy payload is shown in Figure 3-11. Trunnion and keel fitting locations in the Orbiter cargo bay are also indicated. The conceptual design detail includes component location, AFD control and display panels, cable diagrams and coolant lines.

Payload Equipment

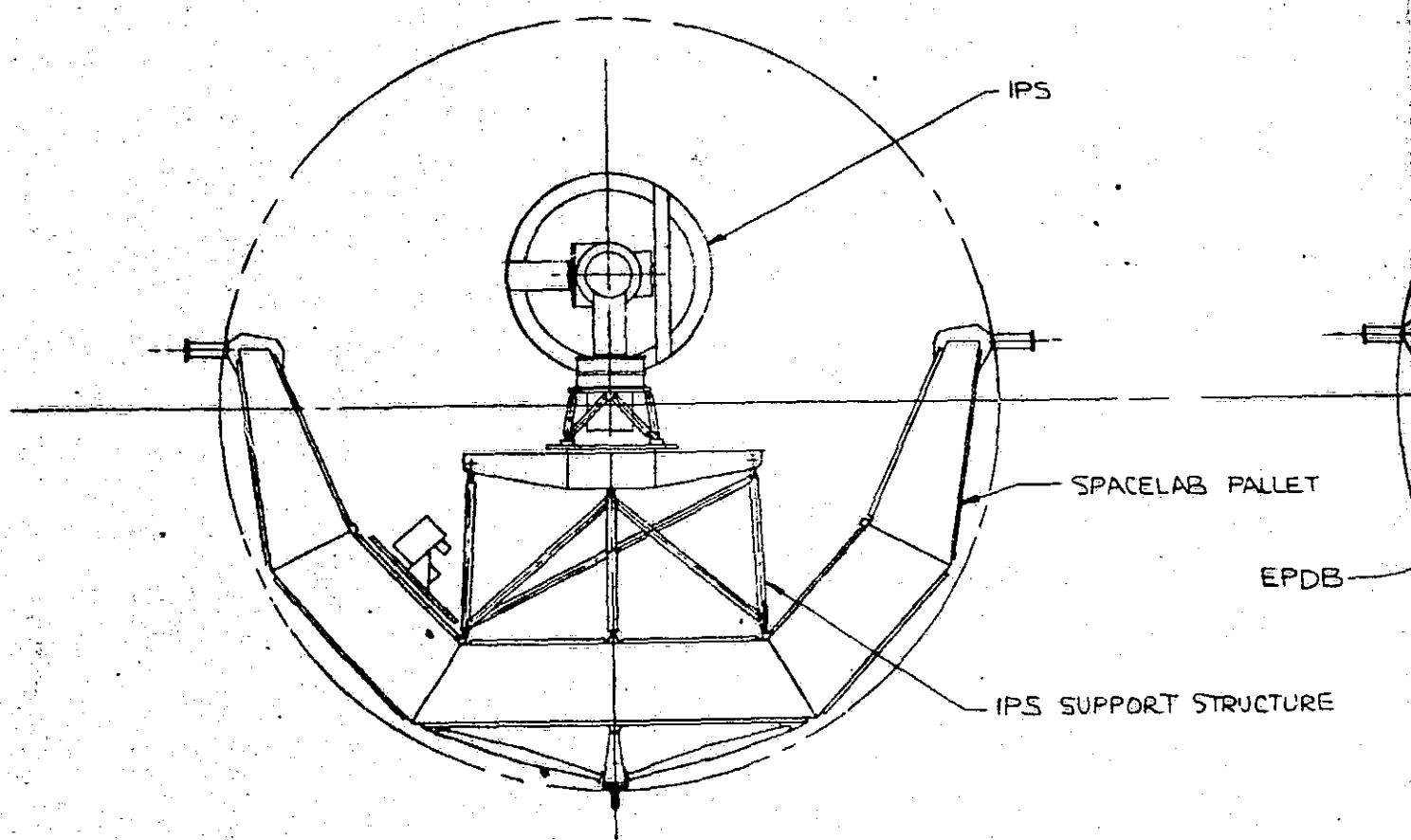
Payload equipment is grouped into four categories: forward, mid, and aft complement, and Orbiter AFD control and display equipment.

Forward Complement

A single pallet is used for mounting of the SIPS. The UV Schmidt camera and photometer are mounted in thermal canisters which in turn are installed in the yoke of the SIPS. As the thermal canisters are an integral part of the sensor design and will be required during sensor environmental testing, the integration of the sensor and the canister was assumed to occur during pre-level IV ground processing activities. Canister-sensor integration is not included in this study. Also, RAU's within the canisters were considered an integral part of the canisters. Similarly, control systems and RAU's of the SIPS were considered to be integral parts of the SIPS. As such, these items were assumed to be installed and verified prior to initiation of level IV ground processing activities.

Installation of the SIPS on the pallet and the two sensor/canisters on the SIPS was considered in this study. Interconnection and verification of electrical and fluid lines between the canister, SIPS, pallet mounted RAU's, EPDB, interconnect stations, and connector brackets is also included in the level IV ground processing activity. Four coldplates, two interconnect stations, two connector brackets, one RAU and one EPDB are mounted on this forward pallet segment. Although these Spacelab provided end items are installed during staging operations at KSC, cable harnesses and fluid lines are installed during Level IV activities. The one exception to this is the "transition" cables which are installed only as required to support functions on subsequent pallets. These cables are interim items, not flight hardware, and are used only during the Level IV phase. At the completion of Level IV, these "interim" cables are removed and replaced as necessary with flight hardware.

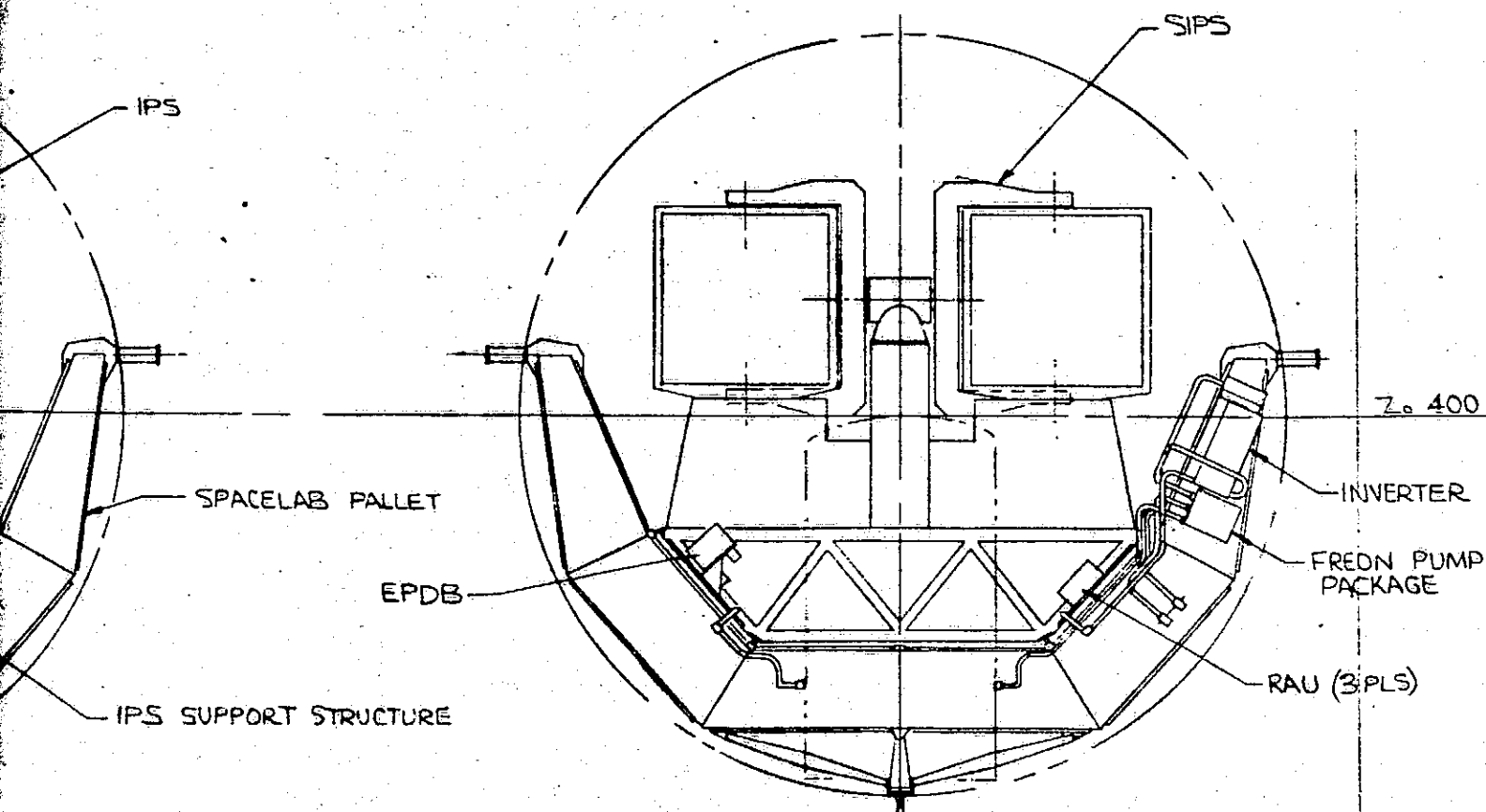
An assessment of alternate approaches for the installation of cable/fluid lines on one pallet for functions/services that a subsequent pallet requires from Spacelab subsystem and/or the Orbiter AFD was conducted. Because of configuration management, change



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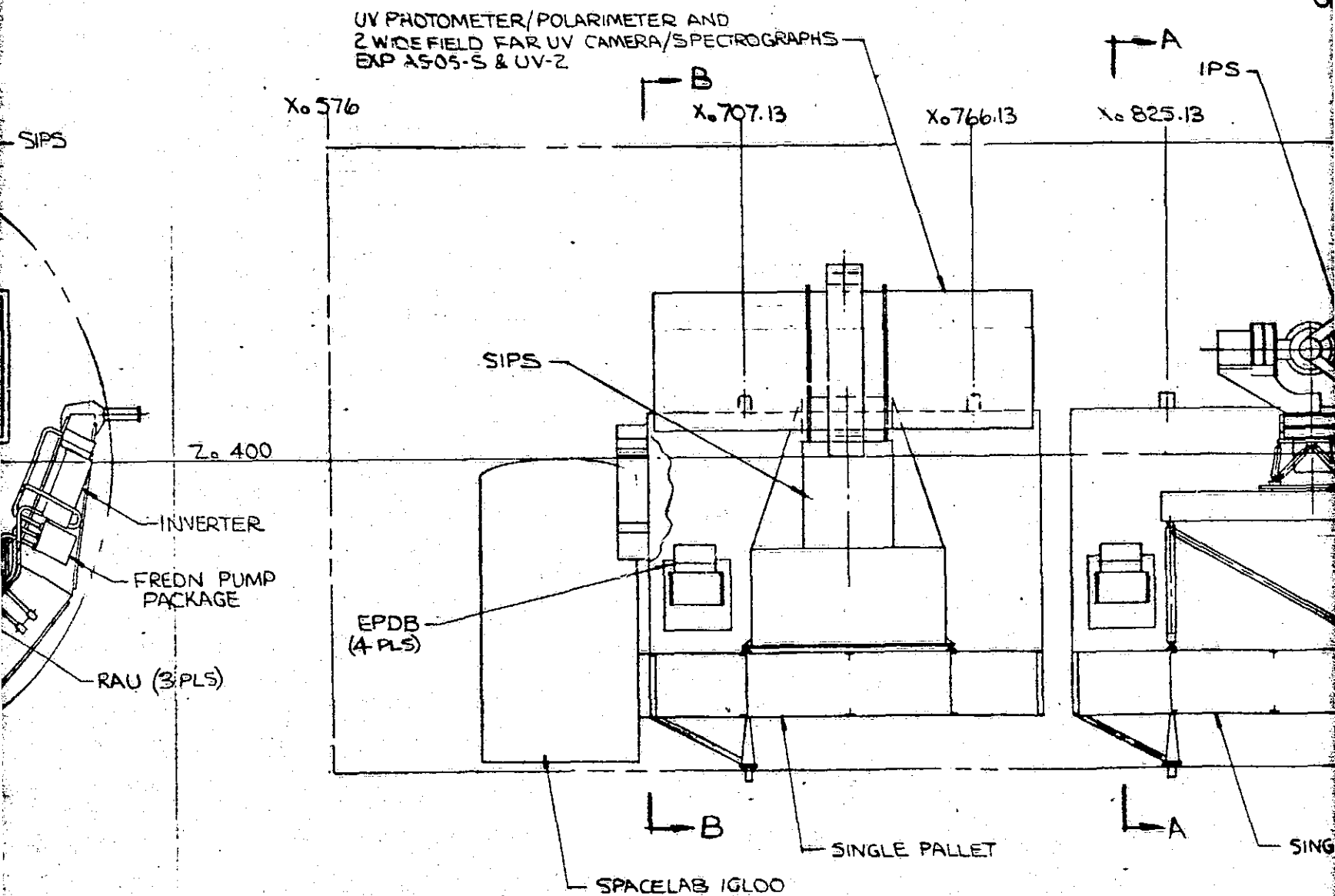
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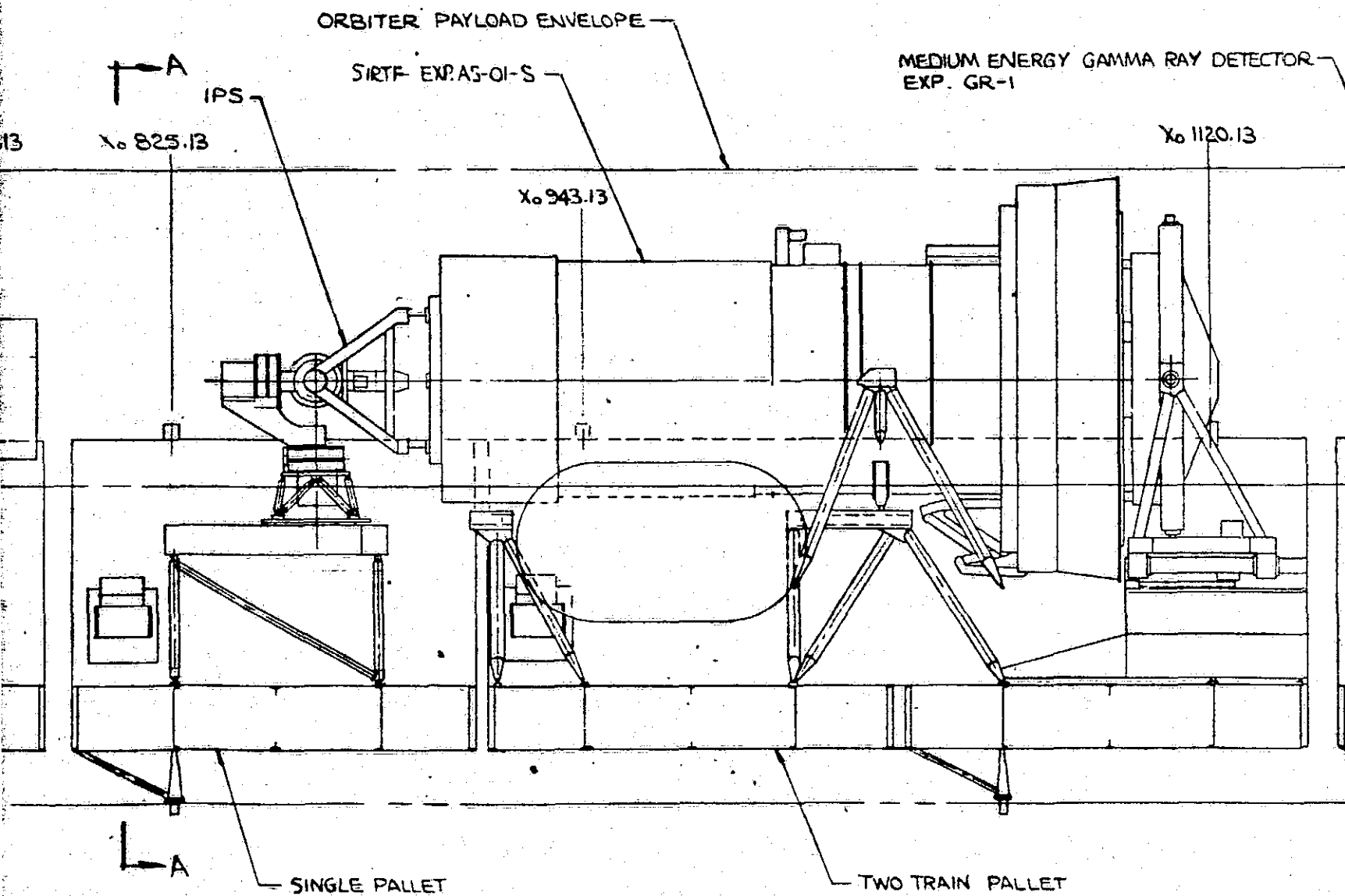
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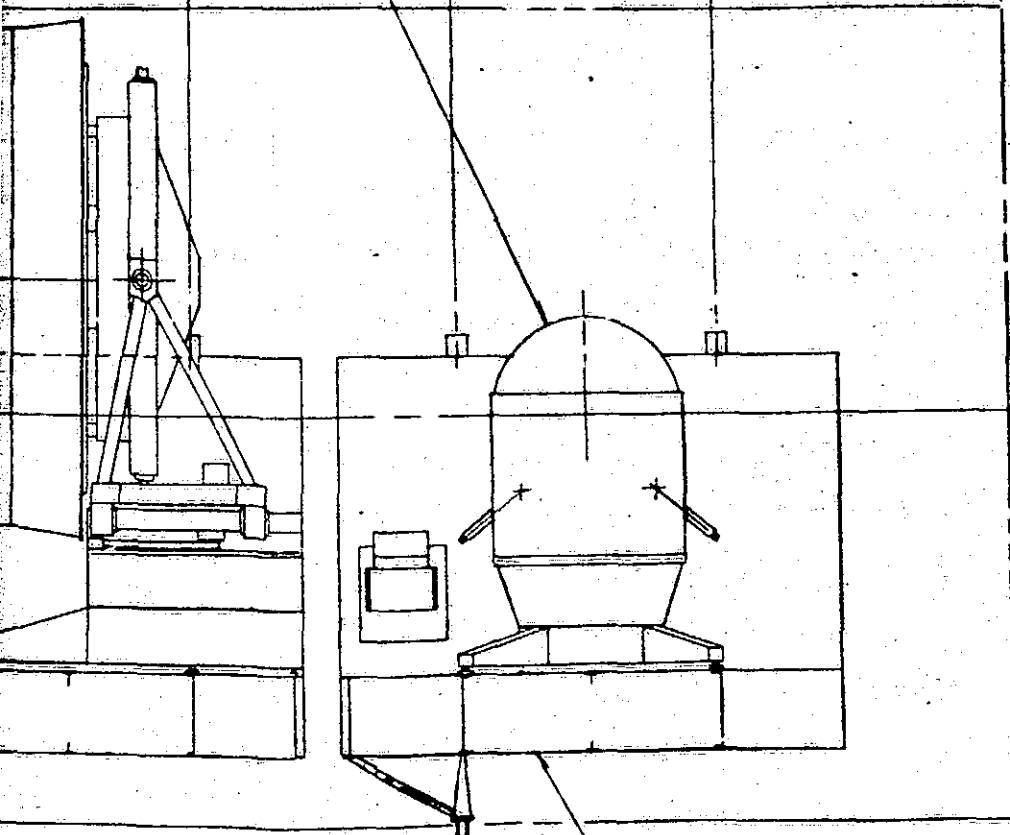
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Figure 3-11. Combined Astronomy Flight Configuration

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COMBINED ASTRONOMY
PAYLOAD

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control, and change policy problems it was determined that installation of these transition cables by the Level IV integration was not advisable. Access to pallet mounting surfaces after installation of experiment equipment and interconnecting cables/fluid lines will be severely restricted. Therefore, the selected approach for installation of transition cables was to install these cables in wire trays during staging operations at KSC.

The Spacelab subsystem Igloo, freon pump, and inverter are also mounted in the forward pallet segment. Installation, interconnectors, and interface verification of the freon pump and inverter was considered in Level IV activities. Igloo integration was restricted to KSC-STS operations.

Mid Complement

The mid complement consists of a single and two pallet segment train combinations. The first pallet segment is used for mounting the IPS. The two pallet train is used for mounting of the SIRTf assembly. Launch and entry/landing loads preclude a rigid interconnection of the IPS and SIRTf and/or a three pallet train configuration. Only a cable (electrical and flex mechanical) interface is maintained between the IPS and SIRTf during these high structural load phases of a mission. A rigid IPS/SIRTf interface is established on orbit by translating the SIRTf via a cable reel mechanism in the IPS mounting ring. Multiple cables interconnect the IPS mounting ring and an adapter ring that is hand mounted on the SIRTf.

The single pallet was considered to be an integrated subsystem which included the IPS, RAU, EPDB, coldplates, and interconnecting cable and fluid lines for operation of the IPS. All of the installation and verification activities for this single pallet were considered to be part of the staging activities at KSC.

Level IV activities for the two pallet train include the mounting of the telescope, telescope support structure, aperture cover, and the experiment cryogenic system. Interconnection and interface verification of the SIRTf assemblies and coldplates, RAU's, EPDB, I/S, and connector brackets are also part of the level IV activities.

Aft Complement

A completely assembled medium energy gamma-ray detector is mounted on the aft pallet segment. In addition, interconnecting cables and fluid lines between the detector assembly, RAU, EPDB, and coldplates are required.

Orbiter Aft Flight Deck

Although significant use of the Spacelab CDMS computer in the Igloo, CRT and keyboard is used for the command, control and data display of the combined astronomy payload, dedicated/hardwired control and display panels are also required. A representative combined astronomy payload AFD control and display layout was synthesized to establish both installation and interface verification requirements.



Available AFD space for mounting of payload control and display panels is shown in Figure 3-12. There is approximately 8.3 square feet of available space at the payload station. The control and display panel requirements (including a CDMS CRT and key-board) are summarized in Table 3-2. Total required panel space is about 6.8 square feet.

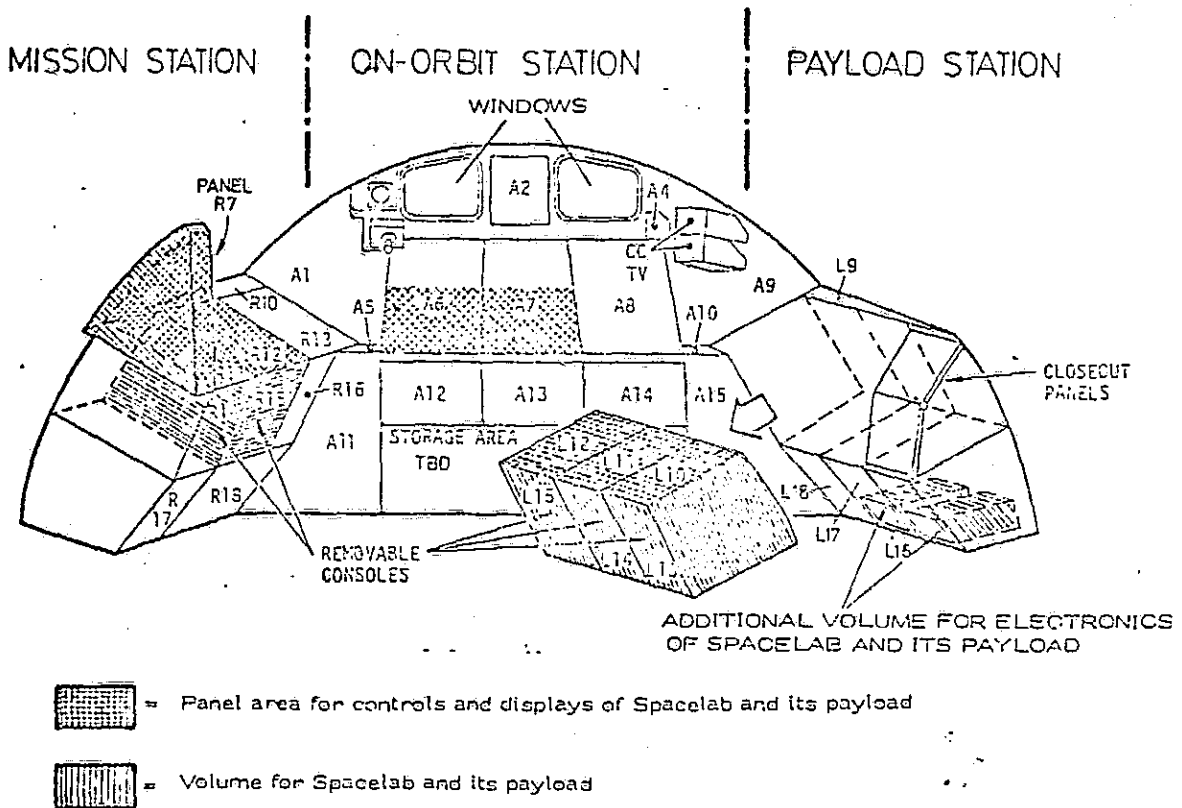


Figure 2 - 21: Layout of Aft Flight Deck (View Looking Aft)

(Reference: Vol. XIV, Rev. D, C 8; ICD 2-05101, IRN-SD-1011)

Figure 3-12. Layout of Aft Flight Deck (View Looking Aft)

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Table 3-2. Experiment C&D Panel Requirements

Panel Name	Length in (cm)	Width in (cm)	Area in ² (cm ²)	Area Ft ²
Panel A SIRTf	21 (53.3)	19 (48.3)	399 (2574.4)	2.77
Panel B SIRTf	7 (17.8)	19 (48.3)	133 (858.8)	.92
UV Photom/Tele.	11 (27.9)	19.(48.3)	209 (1349.5)	1.45
Far UV Schmidt Cam/Tele.	5.75 (14.6)	8 (20.3)	46 (296.5)	.32
Med Energy Gamma Ray Det.	6.25 (15.9)	13 (33.0)	813 (525)	.56
IPS	6 (15.0)	6 (15.0)	36 (232.3)	.29
SIPS	6 (15.0)	13 (33.0)	78 (501.9)	.54



SIRTF Panel A. This control and display panel is shown in Figure 3-13. Because of the extensive SIRTF CDMS interface, the Spacelab CRT/keyboard is included in this panel for reference only and may not be the final flight configuration. The primary functions of this panel are to control the SIRTF experiment and display real time status data of the SIRTF equipment. The capability to update the SIRTF mission plan is also included. Manual and automated control of the IPS and SIRTF are provided. The Video Inertial Pointing System provides monitoring of infrared targets. Hardwired controls for activating, trouble shooting, and stowing experiment equipment are also included. General purpose functions for the payload such as event timers, mission timers, and recorder controls are also incorporated on this panel.

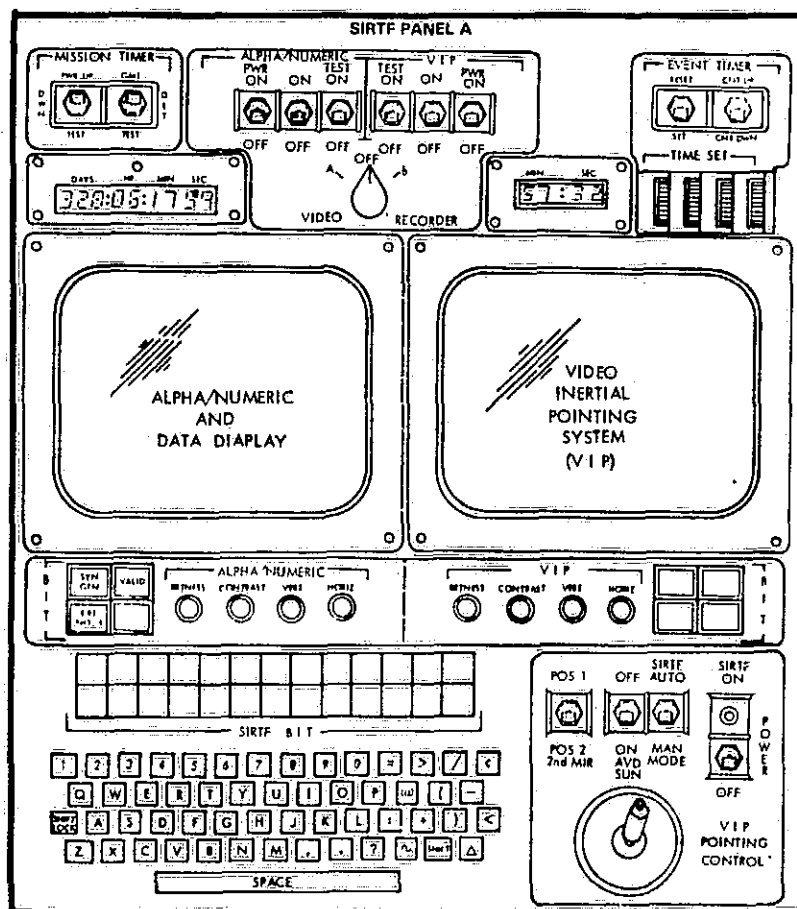


Figure 3-13. Control and Display Panel -
Combined Astronomy

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SIRTF Panel B. Panel B (Figure 3-14) is a dedicated panel used primarily as a hard-wire backup to critical functions on the SIRTF. The ability to directly apply power to the telescope trunnions, the telescope cover lock, cover retract and the telescope sunshade is provided. In addition, manual control is provided for the telescope cryogenic system to maintain positive superfluid flow via direct wiring to the cryogenically immersed heater. Continuous readout is also provided for the cryogenic quantity and system pressure.

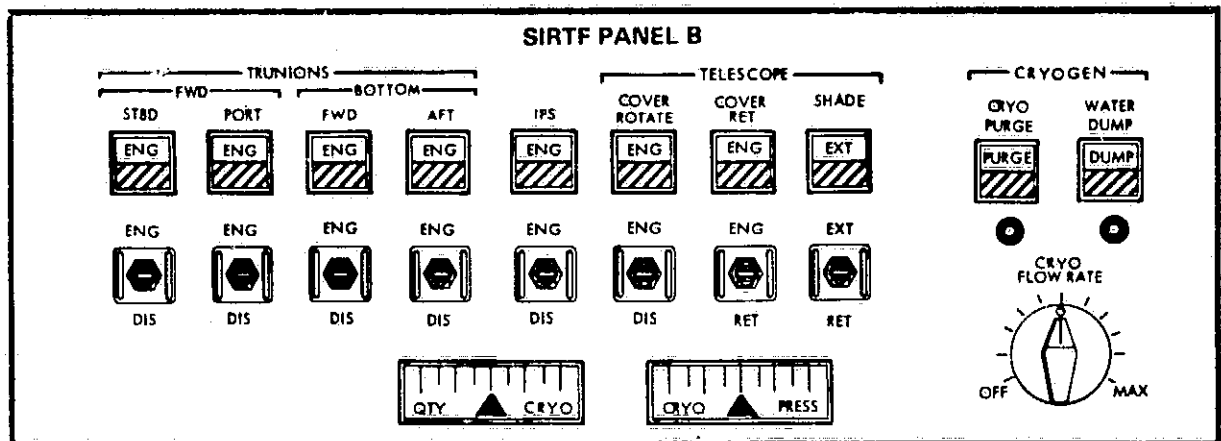


Figure 3-14. Panel B-SIRTF Experiment - Combined Astronomy

The pre-entry cryogenic purge to remove the potential of overpressurization by the cryo-system is activated from this panel. A positive switch is provided along with a talkback device for this activity. Water storage dumping is also performed from this panel via a switch and a talkback status indicator.

Ultraviolet Photometer/Telescope. In addition to the CDMS interface and general purpose functions of SIRTF Panel A, a dedicated panel for this experiment is provided (Figure 3-15). Individual control of the power to each of the eleven (11) detectors and their associated electronics is provided. This switching method was selected to facilitate immediate operator control should a malfunction occur. Should any anomaly exist, a warning talkback and/or an audio tone is activated to alert the Payload Specialist. The faulty subsystem is identified by a status light above the power switch controlling that detector.

Additional capability was included to control Calibration sources, command status, tracking and lock-on control, and a star presence and magnitude meter.

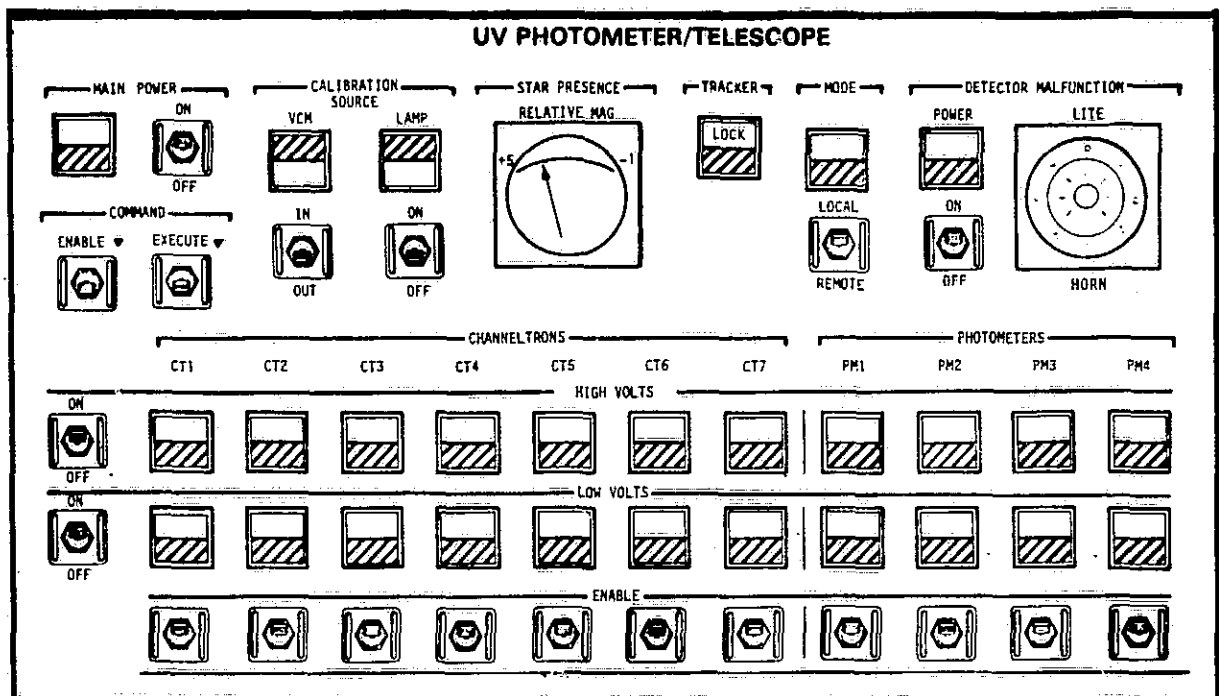
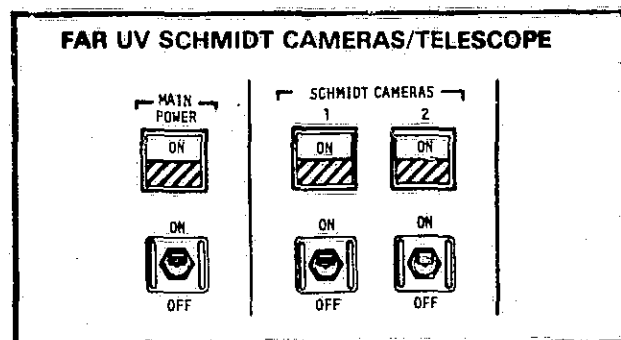


Figure 3-15. UV Photometer/Telescope Dedicated Panel - Combined Astronomy

Far Ultraviolet Schmidt Camera/Spectrograph. Scientific data acquired by the electrographic Schmidt camera is recorded on film and returned to earth for processing and analysis. Thus, there is no scientific data interface with the Spacelab CDMS or real time displays. Data acquisition requirements are limited to housekeeping/monitoring of instrument operation. In addition, a closed-circuit low-light-level television camera, aligned with the view direction of the instruments, is used to verify the pointing direction, and to monitor pointing stability and absence of stray light sources in the instrument fields of view. The Orbiter CCTV monitor is used as required for such on-orbit video viewing.

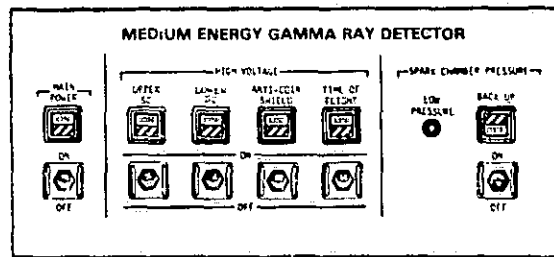
Primary control of the experiment equipment is through the CRT/keyboard provision provided by Panel A-SIRTF. However, some dedicated functions have been identified and are indicated in Figure 3-16.

Figure 3-16. Far UV Schmidt Camera/
Dedicated Panel - Combined Astronomy





Medium Energy Gamma Ray Detector. The Gamma Ray Detector, as with the other experiment equipment, is primarily controlled with the CRT/Keyboard (Panel A-SIRTF). Although the detector is substantially passive in design, some command and display functions will be accomplished via the CDMS. A small number of functions require hardwire control (Figure 3-17). Main power and high voltage control were of prime concern for both the upper and lower spark chambers, plus the anti-coincidence shield. Pressure monitoring and pressure backup-control were considered secondary safety-required items along with the indicator.



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Figure 3-17. Medium Energy Gamma Ray Detector Dedicated Panel

IPS and SIPS Pointing System Dedicated Panels. In addition to the experiment dedicated C&D panels, both an "Instrument Pointing System" and "Small Instrument Pointing System" C&D panels have been added. For the IPS, a main power, ring coupling (IPS to telescope), and jettison hardwire functions were determined to be the dedicated requirement (Figure 3-18). In the case of the SIPS, the minimum hardwire function requirements are the main power, launch/entry latches, and jettison (Figure 3-19). It is noted that the "Jettison" activation switches will not normally be located on the experiment dedicated control panels but rather on the "Jettison Panel" being proposed as a standard Orbiter Aft Flight Deck Panel. The "jettison" switches shown in Figures 3-18 and 3-19 are shown for continuity only.

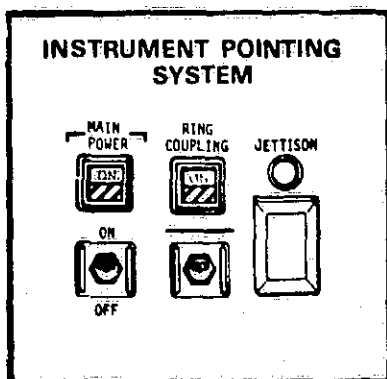


Figure 3-18. IPS Dedicated Panel

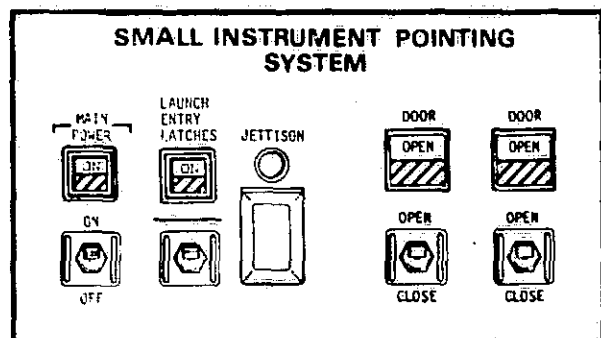


Figure 3-19. SIPS Dedicated Panel



Payload Cabling

The development of the payload interconnecting cable diagram was based upon the functional interface diagrams for each experiment. These functional diagrams are presented in the Combined Astronomy GPR EDP's in Appendix B. The Combined Astronomy payload electrical interconnection diagram is presented in Figure 3-20. Functions include commands, power distribution, data, television coax, and Spacelab subsystem support.

Cable harnesses which encompassed the individual electrical connections were synthesized. These harnesses and their estimated lengths are summarized in Table 3-3. Harnesses were synthesized based upon the type of function (signal or power or pyro) and a study imposed guideline of a maximum of 40 wires per connector. Transition cable across pallets are not included. As discussed in the section on Payload Configuration in the SIRTf section, transition cables and fluid lines are installed during staging operations at KSC.

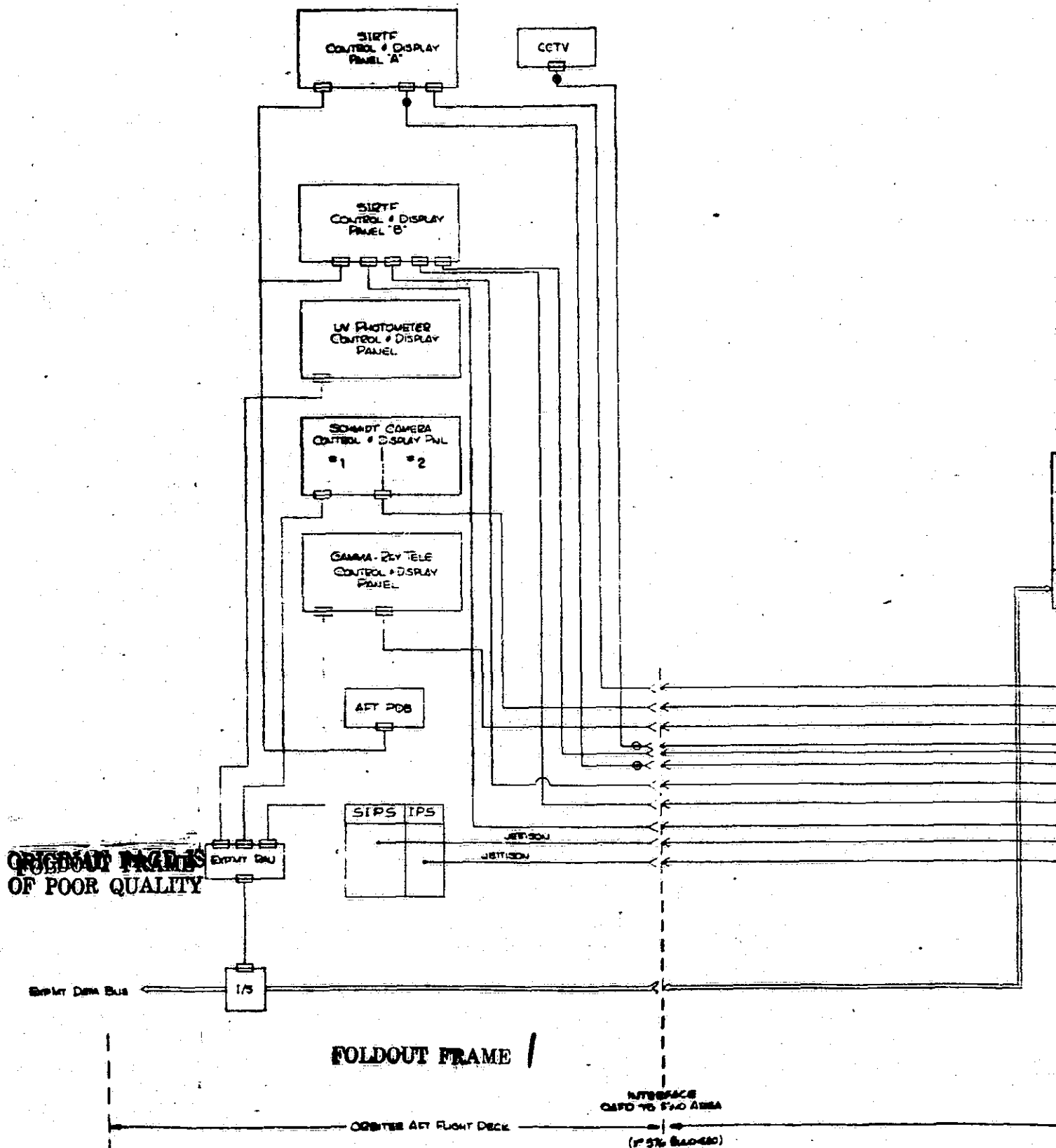
Payload Fluid Lines

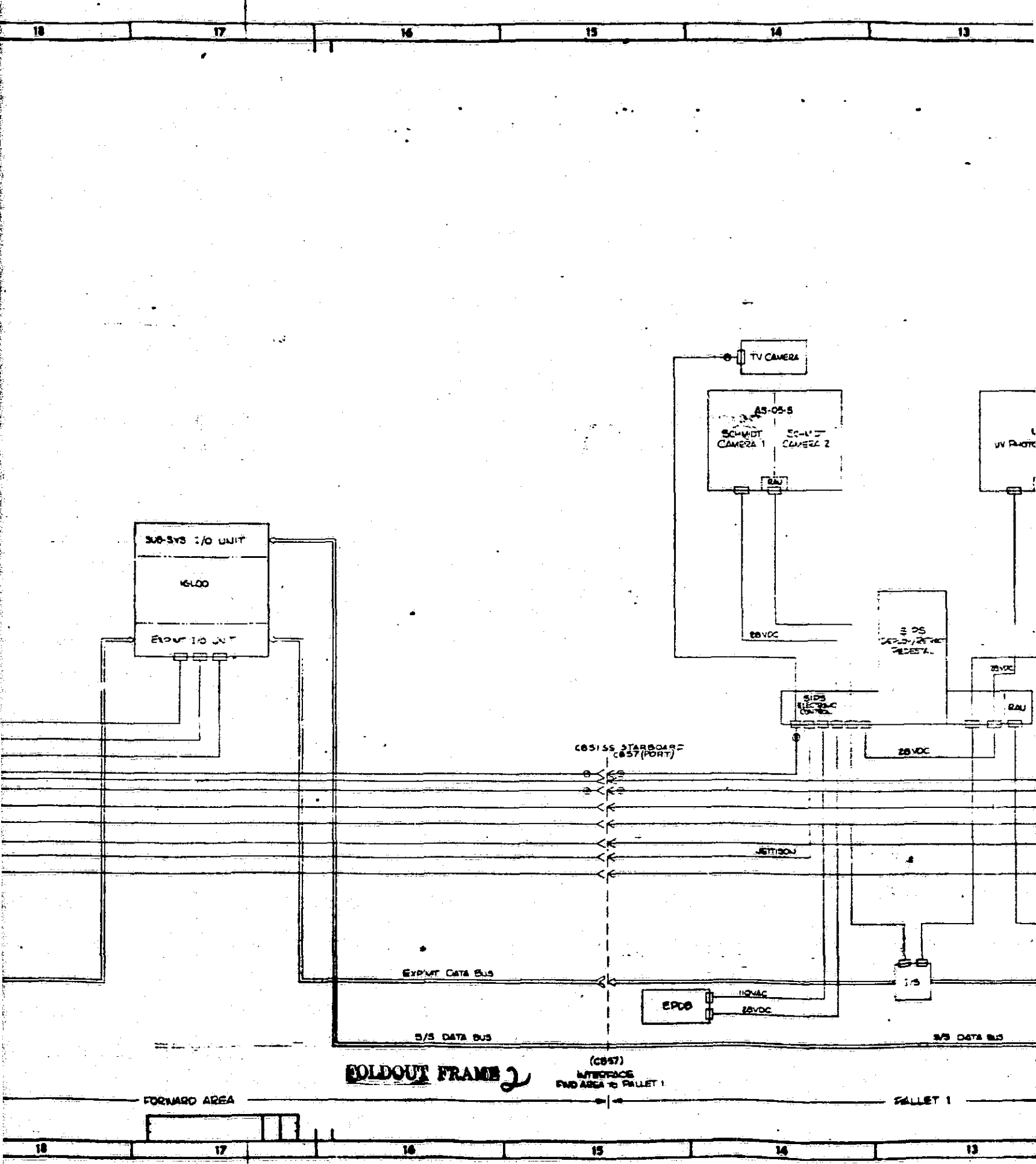
For a pallet only configuration such as the combined astronomy payload, the freon cooling loop interfaces directly with the Orbiter payload heat exchanger at station X₀630. Only the primary "supply" and "return" connections are used with a pallet only payload.

The "supply" termination is connected directly to the Spacelab inverter coldplate on the lead pallet and thru to the multiple coldplates in the Igloo. Coolant is plumbed from the Igloo to the other coldplates in the forward pallet and thence to coldplates on the subsequent pallets. A return line connects the last coldplate on the aft pallet with the Spacelab freon pump on the lead pallet. The loop is completed with a line from the freon pump to the "return" termination on the payload heat exchanger.

The fluid lines for the combined astronomy payload are illustrated in Figure 3-21. Each line and its approximate lengths are listed in Table 3-4. Allowances for evasive routing, and avoidance of obstructions were included in the length estimates.

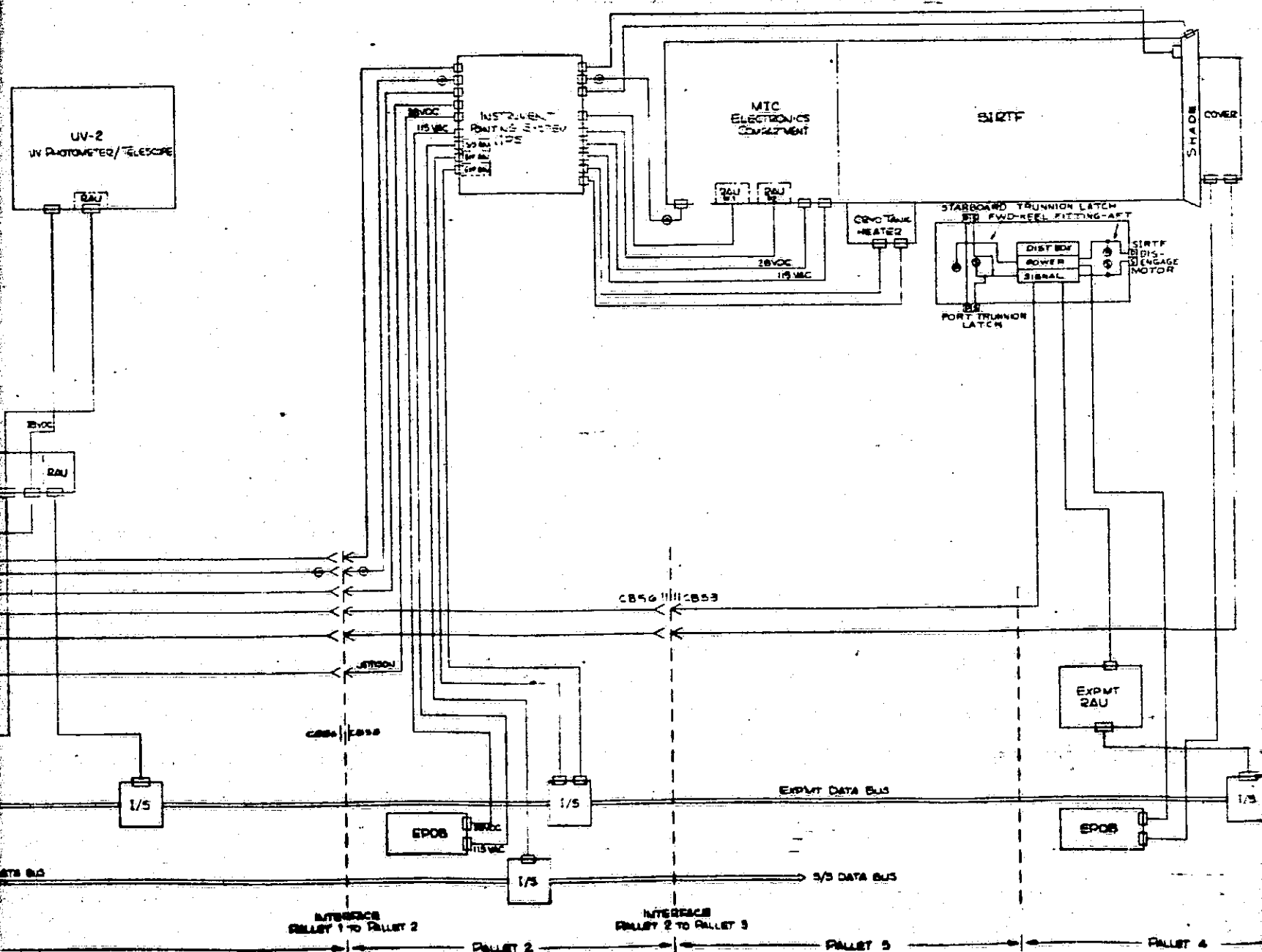
Transition fluid lines were considered to be comparable to electrical transition cables and thus, were installed during staging operations at KSC. Interconnection of the heat exchanger and the lead pallet is part of Level I integration in the OPF.

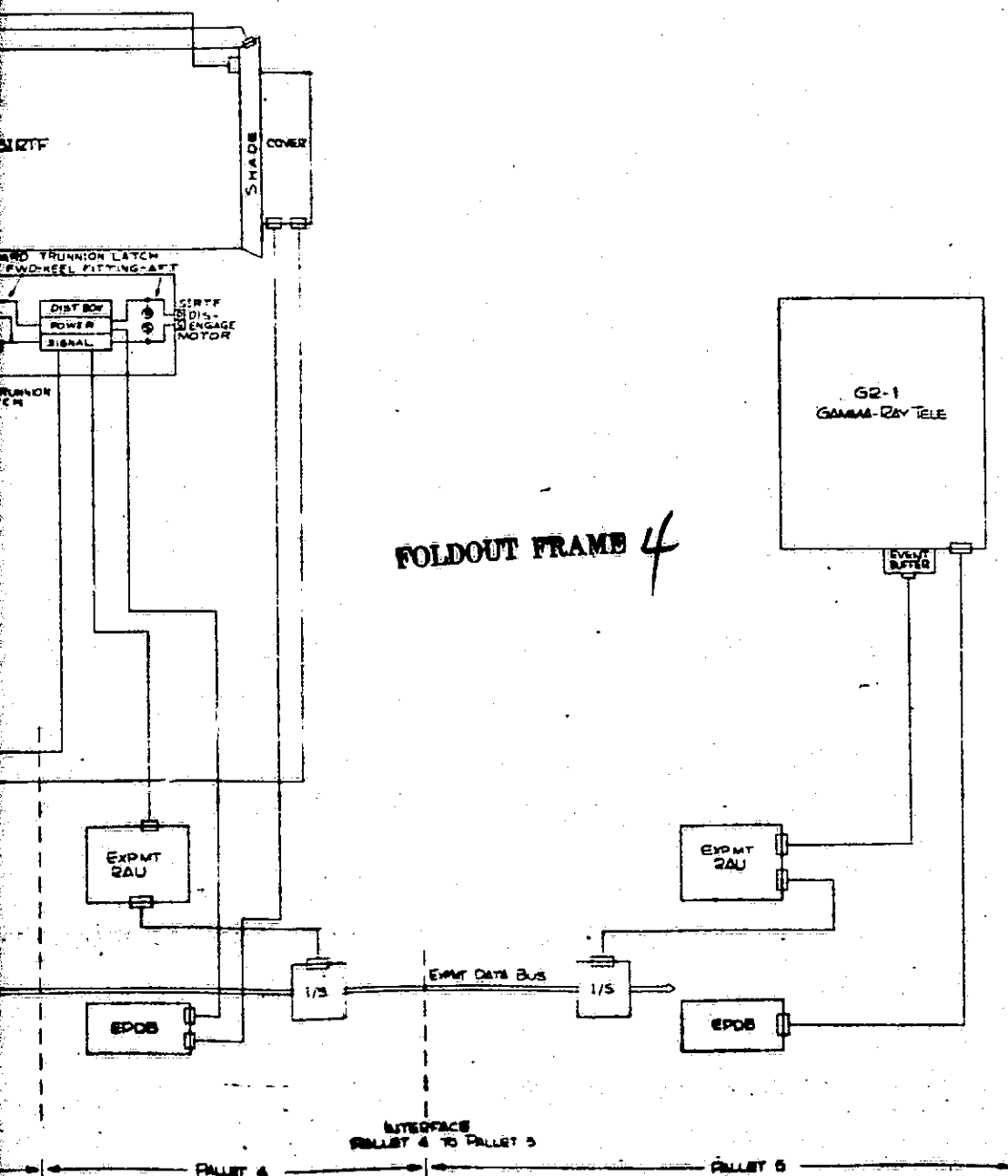




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Figure 3-20. Combined Astronomy
Interconnecting Cable Diagram

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REF ID: A60001		National Interconnecting Cable Diagram - Combined Astronomy Payload	
INTERCONNECTING CABLE DIAGRAM - COMBINED ASTRONOMY PAYLOAD		J 03953	

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Table 3-3. Combined Astronomy-Cable Summary

Cable Identification	Description	From	To	Length (Ft)
FORWARD COMPLEMENT				
PC 1	400 cyc. power	EPD8-1	Control Elecs Unit	6
PC 2	DC power	EPD6-1	Control Elecs Unit	6
SC 1	Signal Cable (Data Cmd) (Schmidt)	SIPS Cntrl Elec Unit	Pallet Exp. I/S	6
SC 2	Signal Cable (Data Cmd) (Photomtr Tele.)	SIPS Cntrl Elec Unit	Pallet Exp. I/S	6
SC 12	Signal Cable (Data Cmd) SIPS	Exp RAU	SIPS Cntrl Elec Unit	6
JC 1	SIPS Jettison (Switch on SIPS Panel)	CB57-1	SIPS Cntrl Elec Unit	
I/S = Interconnect Station				
MID COMPLEMENT				
PC 3A	28V DC	EPD8-2	IPS Base Cntrl Brkt	4
PC 3B	28V DC	IPS's Ring Cnctr Brkt	MIC	5
PC 4A	115 AC	EPD8-2	IPS Base Cntrl Brkt	4
PC 4B	115 AC	IPS's Ring Cnctr Brkt	MIC	5
PC 5	28V - Trunnions	EPD8-4	Pwr/Sgnl Distr Box	9
PC 6	28V - Cryo Heater	IPS Ring Cnctr Brkt	Cryo Heater	7
PC 7	28V - Cover Power	EPD8-4	Cover	12
PC 8	28V - Sunshade	IPS Ring Cnctr Brkt	Sunshade	18
JC 2	IPS Jettison	CB53-2	IPS Base Cntrl Brkt	
SC 3	Signal MIC Exp. RAU-2	IPS Ring Cntrl Brkt	Exper MIC RAU No. 2	5
SC 4	Signal MIC Exp. RAU-1	IPS Ring Cntrl Brkt	Exper MIC RAU No. 1	5
SC 5	5 Func. Cable Panel B: 1. Fwd Keel, 2. Aft Keel, 3. Stbd Trunnion, 4. Port Trunnion, 5. SIRTIF Disengage motor.	CB53-3/4 (Front)	Pwr/Sig. Distr Box	8
SC 6A	Shade Control Signal	CB53-2	IPS Base Cntrl Brkt	3
SC 6B	Shade Control Signal	IPS Ring Cntrl Brkt	Sunshade	13
SC 7A	Cryo Sig - Panel B	CB53-2	IPS Base Cntrl Brkt	3
SC 7B	Cryo Sig - Panel B	IPS Ring Cntrl Brkt	Cryo Tank Heater	7
SC 8A	MIC Video Signal 4.5 MHZ	CB53-2	MIC Base Cntrl Brkt	3
SC 8B	MIC Video Signal 4.5 MHZ	IPS Ring Cntrl Brkt	MIC	5
SC 9	Keyboard Signal Trunnions & Disengage Mtr	Exp. RAU-4	Pwr/Signal Distr Box	9
SC 10	Cover Signal - Panel B	CB53-3 (Front)	Cover	21
AFT COMPLEMENT				
PC 9	Power	EPD8-5	Gamma Ray Exper.	6
SC 11	Signal	Exper RAU's	Gamma Ray Exper.	6

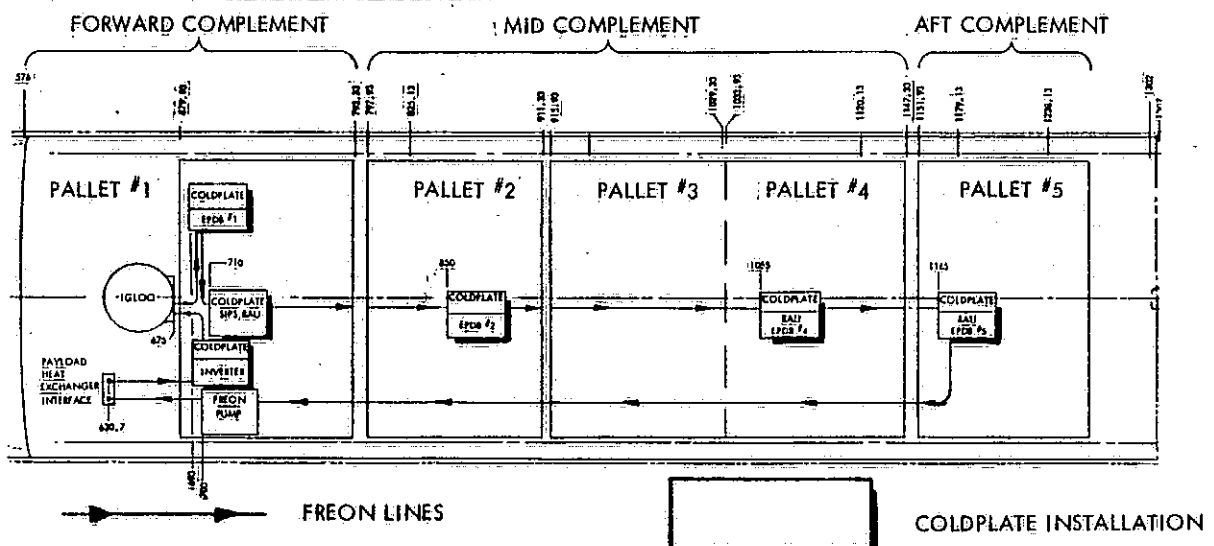


Figure 3-21. Fluid Line Installation



Table 3-4. Freon Coolant Lines - Combined Astronomy

FROM	TO	APPROX. LENGTH
Coolant Dist. Panel STA. 630.7	Inverter C/P STA. 693	100"
Inverter C/P STA. 693	Igloo STA. 675	36"
Igloo STA. 675	EPDB #1 C/P STA. 693	
EPDB #3 C/P STA. 693	SIPS-RAU C/P STA. 693	98"
SIPS-RAU C/P STA. 710	Aft End Pallet #1 STA. 793.3	96"
Fwd End Pallet #2 STA. 797.93	EPDB #2 STA. 850	72"
EPDB #2 C/P STA. 850	Aft End Pallet #2 STA. 911.3	94"
Fwd End Pallet #3 STA. 915.9	Aft End Pallet #3 STA. 1029	144"
Fwd End Pallet #4 STA. 1033.93	EPDB (#4), RAU (SIRTF) C/P STA. 1055	18"
EPDB (#4), RAU (SIRTF) C/P STA. 1055	Aft End Pallet #4 STA. 1147.33	108"
Fwd End Pallet #5 STA. 1151.93	EPDB (#5), RAU (Gamma Ray) C/P STA. 1165	24"
EPDB (#5), RAU (Gamma Ray) C/P STA. 1165, +Y	Across Pallet #5 STA. 1165, -Y	98"
Across Pallet #5 STA. 1165, -Y	Fwd End Pallet #5 STA. 1151.93	24"
Aft End Pallet #4 STA. 1147.33	Fwd End Pallet #4 STA. 1033.93	124"
Aft End Pallet #3 STA. 1029.33	Aft End Pallet #3 STA. 915.93	124"
Aft End Pallet #2 STA. 911.33	Fwd End Pallet #2 STA. 797.93	124"
Aft End Pallet #1 STA. 793.33	Freon Pump STA. 700	120" ±2"
Freon Pump STA. 707	Coolant Dist. Panel STA. 645	72"



4.0 LIFE SCIENCES PAYLOAD

INTRODUCTION

Life Sciences research includes biomedicine, biology, man-systems integration, and life support/protective systems. Biomedicine includes research devoted to (1) understanding character, time course and mechanisms of physiological, anatomical, behavioral, and functional changes in man exposed to the space environment; and (2) providing criteria for countermeasures in support of manned space flights. Biology includes research devoted to (1) understanding the mechanisms of significant changes induced by the space environment on animals and cells and tissues as models wherein the investigation cannot be done easily on man; and (2) understanding the role of gravity and biological periodicities on various biological processes at the subcellular, cellular, tissue, organ, and organism levels.

The Life Sciences payload used in this study consists of a representative experiment complement that uses the Spacelab long module configuration without a pallet. Twenty-three experiments are contained in the module; one experiment is installed in the payload station of the Orbiter AFD. The experiments are listed in Table 4-1. The primary source/contacts for experiment data are also indicated.

The complement of experiments and experiment equipment used as the representative Life Sciences payload are an adaptation of the joint JSC/ARC simulation, LB-SMD-III-1 dated December 31, 1976. Modifications were incorporated to reflect Spacelab and operational constraints.

The 24 experiments of this representative Life Sciences payload are diverse in scope, procedures, and objectives. In terms of objectives, virtually all of the experiments pertain to analyzing various physiological effects of exposure to zero-g. Some experiments (X-27, X-68, and X-74) pertain more directly to the effects of stress and space flight duration. Two experiments (X-51 and X-66) pertain to analyzing the mechanisms involved in motion sickness.

In use of equipment and procedures, other commonalities are found among the experiments. Considerable volume is devoted in the facility to commonly shared biological specimen retention and handling. Eleven experiments (X-3, -10, -11, -12, -13, -21, -23, -27, -59, -60, and -68) use rats or mice for experimental procedures. Similar techniques of handling and surgery are generally required. Three experiments (X-15, -39, and -76) make use of monkeys. Again, similar handling and care are required, with some commonality of equipment. Two experiments (X-42 and X-66) use unique life forms—drosophila and bull frogs respectively. The balance of the experiments (X-5, -8, -49, -51, -58, -68, -74, -75, and -77) use human subjects.

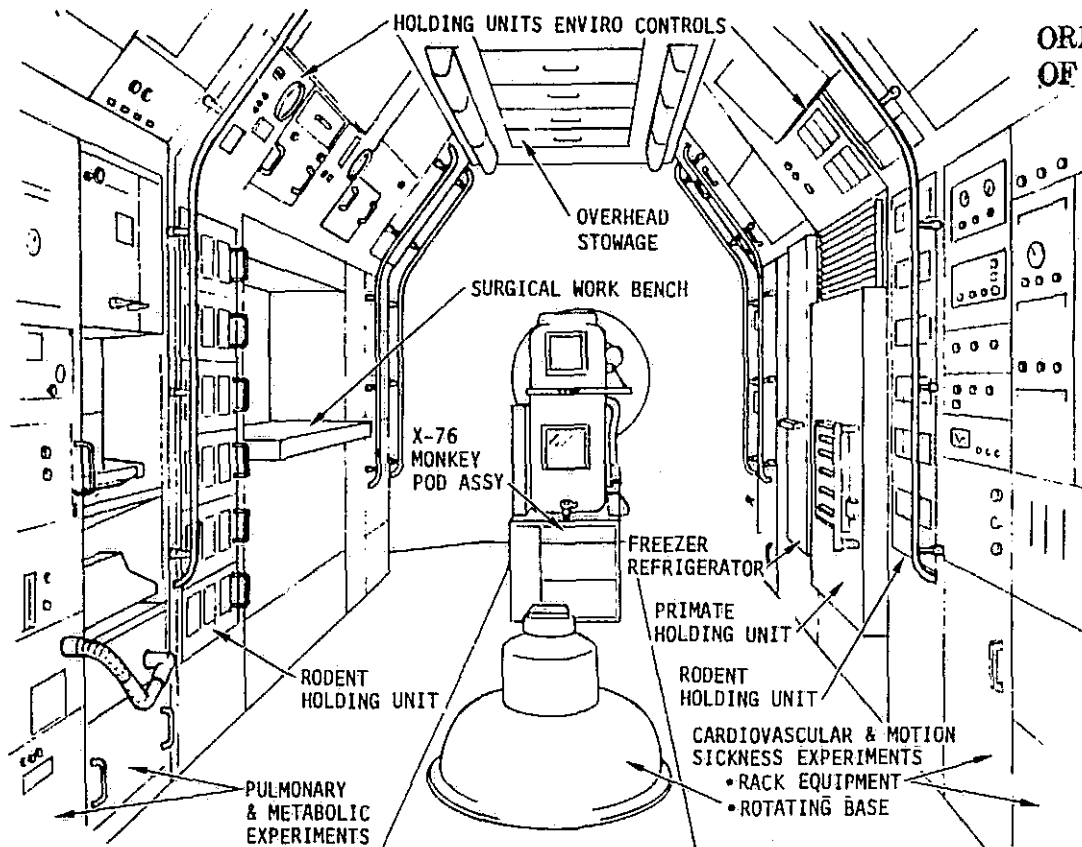


Table 4-1. Life Science Experiment Complement

Expt. No.	Title	Study Contract Center
(1) X-3	Rat Collagen Turnover	ARC
(2) X-5	Biofeedback	ARC
(3) X-8	Insulin Resistance	ARC
(4) X-10	Rat Plasma Somatomedin Concentration	Stanford/ARC
(5) X-11	Rat Urinary Excretion of 3-Methyl Histidine	ARC/JSC
(6) X-12	Rat Proteolytic Concentration in Muscle	Univ. of Texas/ARC
(7) X-13	In Vivo Muscle Protein Degeneration	Univ. of California/ ARC
(8) X-15	Monkey Static-Otolith Activity Change	ARC
(9) X-21	Mice Vestibulo-Cerebellum-Vomiting Center and Hypothalamic-Pituitary-Endocrine Axis	ARC
(10) X-23	Rat Brain & Renal Renin-Angiotensin Alteration	Penn State/ARC
(11) X-27	Rat Lymphoid Tissue Histopathological Changes	ARC
(12) X-39	Monkey Resorption Rate Changes	ARC
(13) X-42	Drosophila Development and Aging	ARC
(14) X-49	Human Cardiovascular Alteration	Stanford/ARC
(15) X-51	Motion Sickness Factors	San Jose State/ARC
(16) X-58	Human Pulmonary Function	UCSD Sch. of Med.
(17) X-59	Rat Metabolism and Heat Balance	ARC
(18) X-60	Rats Pyrogenic Fever-Salicylate Interaction	ARC
(19) X-66	Otolith Response Adaptation as a Function of CNS Output	JSC
(20) X-68	Erythrokinetics in Man	JSC
(21) X-74	Cellular Immune Response in Man	Baylor Univ.
(22) X-75	Basal and Light Activity Metabolism	JSC
(23) X-76	Monkey Cardiovascular Dynamics	Univ. of California/ ARC
(24) X-77	Urine Electrolyte Determination	JSC



Figure 4-1 illustrates the interior arrangement of the Life Sciences experiments in the Spacelab module. This view, looking aft, illustrates the key features of the Life Sciences payload. The majority of equipment items are installed in standard Spacelab racks. These divide almost evenly by volume between standard electronic or electro-mechanical units (amplifier, oscilloscopes, spectrometer, etc.) and special bioscience support elements (specimen holding units, surgical workbench, refrigerator, etc.).



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Figure 4-1. General Arrangement - Life Sciences

In addition to the rack-mounted equipment, significant floor installations are required. The monkey pod installation provides an environmentally controlled chamber for two primates with automatic feeding and water systems and a controlled lower body negative pressure. The rotating base assembly supports either a chair or gimballed platform assembly (normally stowed) and provides for controlled angular rotation or tilt rates.

Considerable volume is required for stowage of miscellaneous items for the Life Sciences experiments. This includes smaller instruments (centrifuge, microscope), consumables (specimen food/water), surgical supplies, syringes, scissors, etc. Some volume is available in the racks including consumables. A multitude of smaller items are contained in the overhead stowage.



EXPERIMENT SUMMARIES

A synopsis of each of the experiments is presented in this section. A detailed description of the experiments including end item descriptions and functional interfaces is presented in the Life Sciences GRRSDP's in Appendix C.

X-3, Rat Collagen

A working hypothesis is that, in weightlessness, bone resorption remains relatively constant, but deposition of new bone is decreased. The objectives of this experiment are to (1) determine bone loss in relation to duration of flight by making measurements of changes in rate of bone resorption and changes in amount of bone deposition with the use of specific double-tagged (^{14}C , ^3H) radioisotopes (hydroxyproline); and (2) determine the levels of j-carboxyglutamic acid in preflight, in-flight, and post-flight bone tissue samples and compare each with ground-based controls. ^{14}C -proline and ^{14}H -proline are injected into rats. Bone samples are later taken and analyzed for bone loss and compared with ground-based controls.

X-5, Biofeedback

The purpose of this experiment is to reduce the symptomatology associated with zero gravity sickness syndrome and thereby shorten the habituation periods and improve the efficiency of Spacelab crew members in space. All crew members will participate for periods of 25 minutes. Preflight and in-flight operant and relaxation therapy will be applied. Autonomic responses to be conditioned include heart rate, respiration rate and volume, blood volume pulse, muscle of the external intercostal and vector electrogastrogram.

X-8, Insulin Resistance During Zero-G Exposure

Studies are proposed to investigate the alterations in glucose tolerance and insulin resistance which are anticipated, following exposure to a zero-g field. The experiments will compare serum glucose and insulin values following a sized glucose drink in human subjects before and after five to six days' exposure to zero gravity. The results of these studies will determine whether administration of glucose to normal subjects during exposure to zero-g, results in a relative glucose intolerance and hyperinsulinemia as noted under conditions of absolute bed rest.

All crew members will participate as experimenters or subjects. The subjects will be given a glucose drink in the morning after an overnight fast. Various blood samples will be drawn and the blood serum will be stored in a freezer for post-flight analysis.

X-10, Somatomedin

Quantitative comparisons of the concentrations of somatomedin C in human plasma collected preflight, in-flight, and post-flight will be made by radio-receptor assay. Preferred collection times are days T-6, T-3, T+3, T+6, and landing +3 and +6. Similar quantitative comparisons of the concentrations of somatomedin C in rat plasma collected from ground-based control rats, and three



groups of five rats sacrificed on days 2, 4, and 6 in-flight is also planned. Blood samples are collected from two crew members before, during, and after flight, and from 15 rat specimens during flight. These samples will be frozen and returned for post-flight analysis.

The objective of these measurements is to gain insight into the mechanism of negative nitrogen balance and loss of muscle protein in weightlessness. For example, is the loss of muscle protein due to changes in the plasma levels of hormones which regulate protein metabolism, or to autonomous cellular mechanisms in atrophying tissues? Somatomedin C is a growth hormone.

X-11, 3-Methyl Histidine

The purpose of this experiment is to monitor the rate of muscle atrophy during weightlessness by measuring the urinary excretion of 3-methyl histidine. All crew members will collect human urine samples. Human and rat urine samples will be collected during the flight and frozen for storage. The rats will be returned live for 7-day post-flight urine collection. All frozen human and animal urine samples will be subjected to post-flight analysis.

X-12, Proteolytic Enzymes

The purpose of this experiment is to determine whether weightlessness-induced atrophy of cardiac, skeletal and bone tissue is associated with increases in intracellular peptidases. The peptidases to be examined are cathepsin D and cathepsin B. The half-life of cytochrome C in red slow-twitch muscle (soleus) will be determined in order to assess atrophy and correlate it with changes in protease activity. Leg and heart samples will be collected from five rats before the flight and on alternate days of the flight (total of 20 rats). The samples will be frozen and returned (with rat carcasses) for post-flight analysis.

X-13, Muscle Degeneration

Net changes in muscle proteins resulting from exposure to total space environments that include changes in gravity, exercise activity, dietary habits, confinement and workload will be identified in this experiment. The study proposes to test the hypothesis that the nitrogen loss caused by weightlessness is due to an increase in gluconeogenesis (formation of carbohydrate from protein). Included as part of the study is identification of the role played by the endocrine system in regulation of net protein changes.

Before the flight, catheters will be installed in the jugular veins of 12 rats; of these, six of the most viable will be carried on the mission. On the sixth day of the flight, two rats will be injected with Alanine-1-¹⁴C. Expired breath, blood, liver and muscle samples will be collected and the tissue samples will be frozen. The remaining animals will be returned live and analyzed along with the in-flight samples.



X-15, Otolith Activity

The change in extra-ocular motor activity caused by removal of the 1-g gravitational force (to zero-g) for an extended period of time and subsequent restoration of the 1-g field will be researched with this experiment. One objective of this experiment is to attempt to establish the reasons for loss of motor coordination experienced in a zero-g environment. In addition, it is expected that the properties of otolith induced vestibule-ocular reflex (VOR) adjustment to the gravity changes can be studied. An important aspect of this investigation is to determine whether pilot-controlled reentry is possible after prolonged space flight, or if such maneuvers will be impossible due to the habituated and readaptation properties of the otolith end organs.

Electrodes in a monkey's skull will sense eye movements when the monkey's supporting chair (skull fixed relative to chair) is accelerated in 0-g and in 1-g environments. Electrode outputs will be recorded. The tests will be performed for a two-minute period of time during and post-flight. Ground operations include identical tests performed simultaneously on control subjects.

X-21, Hypothalamic Structure

The purpose of the experiment is to investigate five potential structural changes in the brain and endocrine system of mice after five to six days in a zero-g environment. A unique feature of the experiment is that such structural changes will be observed by electron microscopy. Regions of concentrated effort for this study are the vestibulo-cerebellum vomiting center and the hypothalamic-pituitary-endocrine axis.

Twenty-five mice will be used; their weights will be measured in preflight and food intake measured in flight. Blood specimens will be collected by perfusion from mouse hearts. Other specimens include mouse brains, liver lobes, kidneys (with included adrenal glands) and testes. Tissue specimens will be preserved by refrigeration and freezing. Mouse remains will be similarly preserved.

Fifteen mice will be placed in cages of the rat transporter and stowed in the Orbiter for return. These will be sacrificed on return and comparative post-flight analysis with the refrigerated and frozen in-flight specimens will be conducted.

X-23, Angiotensin

The purpose of this experiment is to determine if alterations in the function of the brain renin-angiotensin system are responsible for the changes in salt/water metabolism observed during space flight. These are expected to be related to the loss of blood volume experienced by astronauts due to a decline in fluid intake and redistribution of blood.

Before the flight, intraventricular (IVT) cannulae will be implanted in 12 flight rats and a ground-based control group. The rats will be weighed before the flight. Inflight, water, saline and food consumption will be measured daily. Urine volume, fecal mass and body mass will also be measured daily and



the specimens will be stored. On the fourth day of flight, three sets of 4 rats each will be injected with Pll3, CSF, and renin. On the sixth day, measurements will be repeated, the 12 rats sacrificed, and the specimens stored and frozen. All specimens will be returned for post-flight analysis.

X-27, Lymphoid Tissue

The determination of the time of onset and progression of alterations in lymph nodes, thymus, spleen, pulmonary lymphoid nodes and Peyer's patches both during and after periods of weightlessness is the purpose of this investigation. It is expected that the results will contribute to the data upon which to base predictions about the consequences of extended zero-g flights, not only on the lymphoid organs, but also on other adaptive mechanisms.

Tissue samples will be collected from five rats on the second and sixth day of the flight, and on the first and 28th day after reentry. The following organs will be removed and preserved: inguinal lymph nodes, spleen, mesenteric lymph nodes, intestinal segments containing at least two Peyer's patches and thymus, lungs and heart en bloc. Tissue samples collected inflight as well as on the first day after reentry, along with the remaining eight animals will be returned for post-flight analysis. The eight returned animals will supply tissue specimens on the 28th day after reentry.

X-39, Bone Resorption

The purpose of this experiment is to examine experimentally the effects of weightlessness on bone strength and biochemistry; to determine if weightless skeletal mineral loss is due to an increased bone resorption rate; to document local and regional skeletal losses; and to assess the effect of loss of osteoid tissue on bone strength.

A Macaca Nemest.ina monkey will be put on a Basel diet 60 days before the flight and weighed once a week. On the first day of flight, a cereal containing ^{48}Ca will be fed to the monkey and 2 ml of ^{46}Ca solution will be injected. 10cc of blood will be obtained by venipuncture at 6 and 12 hours following ^{46}Ca injection. On the second day, a ^{48}Ca diet will be fed and a 5 ml serum sample obtained. The following flight days' procedure will be the same as for the second day. The bone calcium turnover in the monkey will be determined by analyzing its blood serum for Ca. All frozen blood samples and unused food will be returned for post-flight analysis.

X-42, Drosophila Aging

The emphasis in this experiment will be to study the effects of weightlessness on the behavior and aging of *Drosophila melanogaster*. Each day of the flight the lights will be turned on in the *Drosophila* storage drawer at 0800 and turned out at 1600. On the second day in space the door separating male and female compartments in one vial will be opened and photographs taken of the resulting mating behavior. Other behavior parameters to be observed are: "walking", flying, grooming, and courtship. The adult flies will then be removed.



After the flight, the embryonic development of *Drosophila* conceived in space will be observed (e.g., male and female yields, time of hatching, body weights, and abnormalities). Changes in these offsprings will also be observed (e.g., such as fine-structure alterations with loss of endoplasmic reticulum and mitochondria and accumulation of lipofuscin; changes in the amount of glycogen and lipid present in the wing muscle and in the fat body).

X-49, Cardiovascular Alteration

The objective of this experiment is to measure the change in human cardiac performance in terms of cardiac volume and peripheral blood flow during and after space flight. All crew members will be instrumented each day of the flight and their physiological data monitored.

Measurement of cardiac performance will be accomplished by methods which are non-injurious and require no penetration of the skin. Blood flow velocity will be measured by backscattered ultrasound (doppler sensors). Temporal artery blood flow will be monitored during liftoff and reentry. An ultrasonic probe (echocardiograph) will be used to determine cardiac output and dimensions. These data can be presented by a single probe for localized information or by a multi-element array for data over an extended region. Arterial pressure and Korotkoff sound signals will be measured by a self-contained cuff inflation system and a microphone transducer/preamplifier combination to detect sound signals. Changes in the pattern of ventricular wall function during weightlessness or in response to exercise, drugs or other provocative tests will be recorded using a single axis accelerometer applied noninvasively over the point of maximum cardiac impulse.

X-51, Motion Sickness

Using the stimuli due to coriolis cross-coupled acceleration, data will be obtained which is expected to allow tentative identification of the mechanisms responsible for coriolis-induced motion sickness experienced in Skylab. Two mechanisms are considered; a general reduction in vestibular function, and a sensory rearrangement that would essentially decouple canal and otolith information.

Crew members serving as subjects will learn their task with one set of practice trials (6 trials) for each test, requiring about 20 minutes per test. One crew member will be tested on days 1 and 5 of the flight and the other on days 3 and 7. A testing sequence similar to the one in space will be required post-flight, on days R+1, R+3, and R+30. The tests will consist of judgements by the subjects of the peak magnitude and duration of their perceived rotation during and following stimulation by each of five levels of cross-coupled stimuli.

X-58, Pulmonary Function

The purpose of this experiment is to determine those aspects of pulmonary function which can be expected to change in the weightless environment. Measurements will be made of changes in parameters such as pulmonary diffusing capacity, pulmonary blood flow, and pulmonary blood volume. The experimental procedure in-flight is noninvasive. Three crewmen will serve as subjects; each crew member will alternately serve as subject and experimenter. The crew members will be trained during preflight in the performance of six tests which involve breathing various gas mixtures for a period of less than 30 seconds each.



X-59, Metabolism

This experiment will determine the normal responses of the thermoregulatory system to extended periods of zero-g.. Two primary measurements will be made on non-tethered rats; deep body temperature measured by small temperature transmitters implanted in the abdominal cavity, and the metabolic rate (oxygen consumptions and carbon dioxide production) monitored continuously by a mass spectrometer for the determination of heat production and energy production.

X-60, Pyrogens

This experiment will determine the response of the thermoregulatory system in six rats to an imposed pyrogenic fever in zero-g, and the effect of salicylate administration on this fever.

Six male white rats known to respond to pyrogenic fever will be the experimental animals. Several tests will be conducted prior to flight to determine the time course and level of fever produced in each of the animals in response to pyrogenic injection. Pyrogen will be administered during flight to three rats on day 2; the other three with pyrogen salicylate. On flight day 4, rats previously injected with pyrogen will then be injected with pyrogen salicylate and conversely, the other rats with pyrogen. Deep body implants of temperature telemetry and accompanying equipment will provide continuous monitoring of body temperature. All rats will be returned for post-flight analysis.

X-66, Otolith Output

This experiment will investigate the influence of the central nervous system in modifying peripheral input and its effect on otolith output in a zero-g environment. Observations during Skylab suggested that behavioral changes related to the otoliths do occur in zero-g.

Preflight training will include training two crew members in experiment procedures, handling of bullfrogs, operation of experiment hardware, and performance of surgical skills necessary to specimen preparation. Inflight procedures will be identical to those used to collect baseline data on the ground during training. Single unit records will be obtained from the saccular branch of the eighth nerve in the bullfrog during off-vertical rotation. The frogs will be constrained during observation and subsequently sacrificed for histological examination.

X-68, Erythrokinetics

The hypothesis that hemolysis is the primary cause of red blood cell (RBC) loss in long duration space flights will be tested with this experiment. Crew members and a group of ground-based subjects as similar as possible to the flight crew with respect to age, weight, sex, physical condition, and overall health will be the subjects in this experiment.



The experiment consists of taking blood samples from the subjects three times in preflight, two times in flight, and three or four times post-flight and comparing these samples with those of the ground-based subjects. Many parameters describing the blood samples and separated serum will be measured after the flight. Some of the tests are:

<u>On Serum</u>	<u>On Whole Blood</u>	<u>On a Fixed Sample</u>
Erythropoietin	Memoglobin	RBC Shape (from stress sample)
Chemistry	RBC Count	
Plasma Volume	Hematocrit	
	Stress Sample	

X-74, Immune Response

The purpose of this experiment is to characterize lymphocytic types and to evaluate lymphocytes for their responsiveness before, during, and after space flight (i.e., zero-g environment). This will have a bearing on the ability of the human immune system to respond to a foreign challenge since the lymphocyte is the primary cell of the system in this response. Each crew member will be required to participate in the experiment on days 2 and 6 of the mission.

Peripheral blood will be obtained before, during, and after the flight. Lymphocytes will be separated and evaluated for their functional capacity to respond to antigenic and toxic stimuli. Immunologic studies will include blastogenic response to specific stimuli such as influenza vaccine and to non-specific stimulus by PHA, Con A and pokeweed mitagen; cytotoxicity assays; and lymphocyte ratios for bone marrow-derived to thymic-derived lymphocytes. Five milliliter blood samples will be required from each flight crew member the day of mission release, on the following day, and days 3 or 4 following the mission. If the last sample is not normal, a further sample during the second week after the mission will be necessary.

X-75, Basal Metabolism

It is the purpose of this experiment to determine how the absence of gravity affects metabolism during rest and during activity, requiring minimal muscular effort. It is postulated that metabolism associated with muscle effort may be reduced in zero-g. Two crew members will be required for four 45-minute experiment sessions. Preflight training will include one 1-hour and two 1-1/2-hour training periods for each crew member for learning performance procedures. No post-flight participation is required. Oxygen consumption and CO₂ production by each of the crew members will be measured during a 30-minute period at a pre-determined time of day when he is completely at rest.

X-76, Cardiovascular and Hemalysis Experiments

This experiment consists of three individual experiment protocols. Two primates, "A" and "B", are housed in individual monkey pods for the conduct of the following described experiments.



X-76-18, Cardiovascular Dynamics

The determination of the relationship of central blood volume, central venous pressure, blood flow distribution, and cardiac output in zero-g is the purpose of this experiment. In addition, cardiac packing and lower body negative pressure (LBNP) will be measured.

One monkey is the subject of this experiment. A University of California monkey pod will confine the monkey. The upper and lower sections of this pod are separated by a diaphragm fitted about the monkey. The upper portion of the pod samples respiration. The lower portion collects excreta and provides for LBNP. Both 24-hour and provocative stress hemodynamic measurements will be made on the monkey periodically over a period of four months prior to the test. Each stress test sequence will consist of two 10-minute recordings within a 16-hour time span. The 10-minute measurement interval will contain a control period, test period with provocation by cardiac pacing and a recovery period.

All data will be collected for selected one week periods during preflight, continuously during flight, and continuously for a minimum of one day post-flight. Surgically implanted biotelemetry (in preflight) permits recording of body temperature, EKG, aortic pressure, and left ventricular pressure.

X-76-33, Hemalysis

It is the purpose of this experiment to determine whether or not the reduction of red blood cell (RBC) mass is caused by accelerated hemalysis in zero-g conditions.

The monkey used in 76-18 experiment is also the subject of this experiment. The monkey will be injected with 2-¹⁴C glycine to label an old cohort of RBC and injected with 2-¹³C glycine to label a young cohort of RBC. Changes in the CO output in the breath during flight will indicate that hemalysis has been altered.

X-76-44, Metabolic and Cardiovascular Adaptation

This experiment will determine changes in the equilibrium levels of central blood volume, red blood cell (RBC) mass, and hemalysis. Basal energy requirements will be determined and thyroid control resetting will be observed.

A second monkey will be the subject of this experiment and will also be confined in a monkey pod. The upper and lower sections of this pod are also separated by a diaphragm fitted about the monkey. Surgically implanted biotelemetry (in preflight) will permit recording of body temperature, EKG, aortic pressure, and left ventricular pressure. The subject will be placed in its pod one week before launch to provide preflight baseline physiological data using ground-support instrumentation. On return to earth, physiological measurements on the monkey will continue for an additional week.



X-77, In-Flight Electrolytes

In this experiment measurements of the total urinary volume and content of key electrolytes in urine contributed by crew members under zero-g will be conducted. The motivation for the experiment is based on the assumption that basic biochemical changes occurring after the onset of weightlessness are rapidly reflected in the parameters to be measured. Each crew member will contribute specimen samples.

A urine measurements system will automatically measure, in real time, the volume of each micturition of each crew member. Similarly, an automatic system will measure sodium potassium, calcium, and chloride ion concentrations on a void-by-void basis.

PAYLOAD CONFIGURATION

The majority of Life Sciences equipments are installed in the Spacelab long module. The long module consists of the core segment, with 2-single and 2-double racks available for experiments plus the experiment segment with 2-single and 4-double racks available. The assembled module is placed in the cargo bay with a Spacelab tunnel adapter, which mates with the orbiter-provided tunnel and outside airlock installation as shown in Figure 4-2.

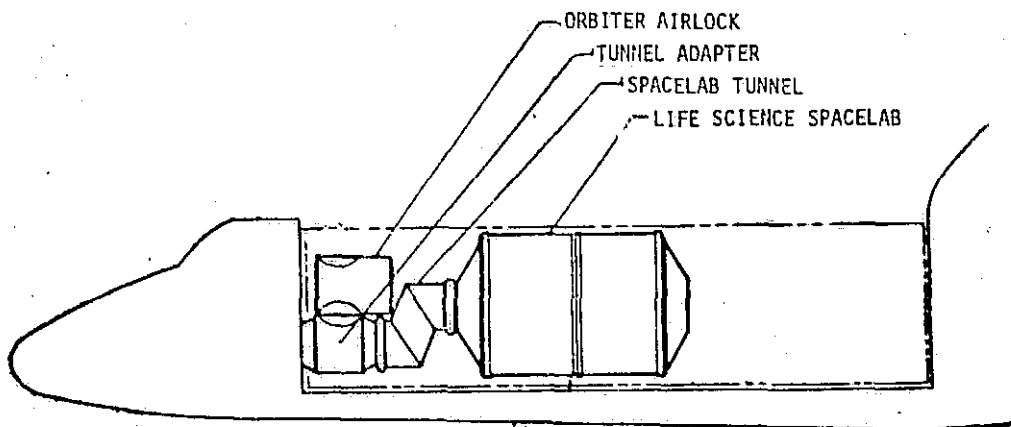


Figure 4-2. Spacelab Long Module Installed in Orbiter

Spacelab Module Rack Arrangement

The experiments included in the module and racks are shown in detail in Figure 4-3. Aft of the Spacelab control center on the starboard side is a double rack of equipment including breathing gas analysis equipment--spirometer, pneumotachometer, mass spectrometer--and supporting electronics. The next single and double rack contain Common Operational Research Equipment (CORE), which are used to support multiple experiments. The next double rack contains metabolic rat cages and instrumentation for Experiments 59 and 60. The last single rack and the single rack on the aft end of the port side

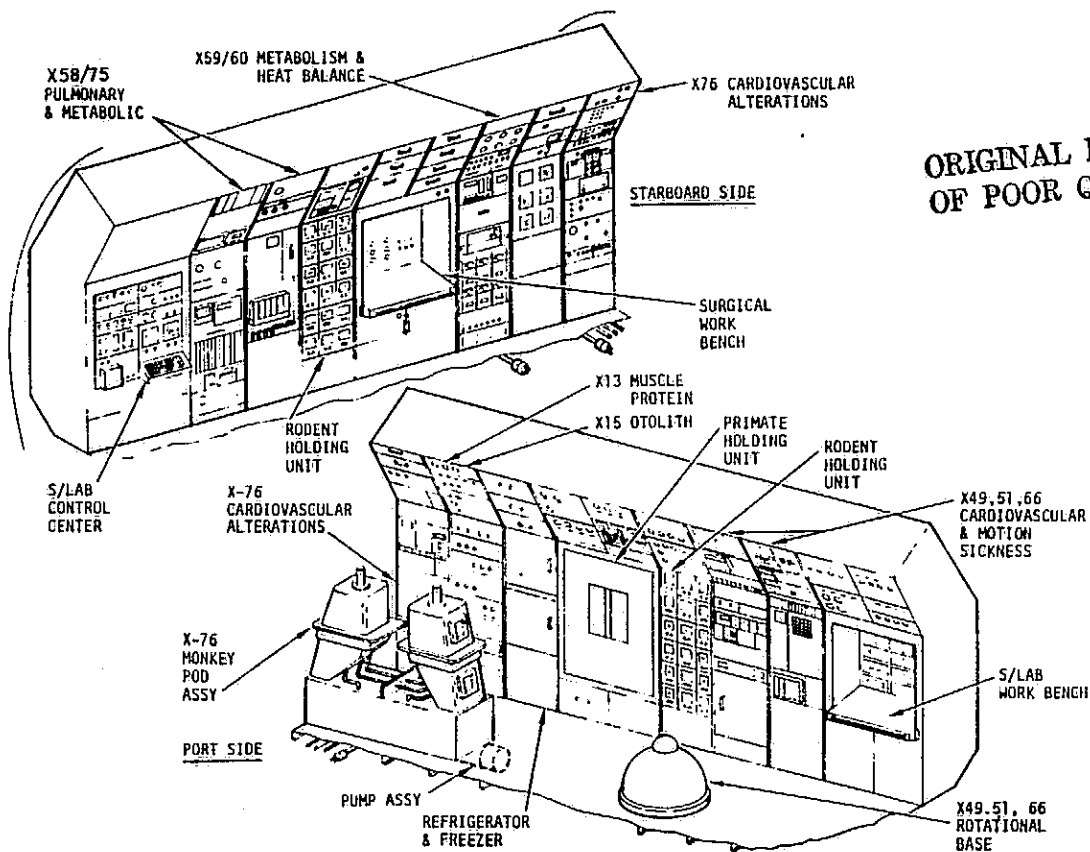


Figure 4-3. Spacelab Module Rack Arrangement - Life Sciences Laboratory

contain pressure control modules and instruments associated with cardiovascular research on the primates in the floor-mounted monkey pod assembly.

The next double rack on the port side is shared by two experiments. Part of the rack is occupied by experiment X-13 for the study of muscle protein loss in rats in zero-g. The other experiment, X-15, uses a primate installed in an oscillating "chair" to measure effects of linear accelerations on the otolith response. The chair is normally stowed, but installed into fittings in the module floor when the experiment is to be performed. The rest of this double rack, and the next double and single rack include primarily CORE items.

The last experiment double rack contains three experiments associated with the use of the rotating base. Experiments X-49 and X-51 use a folding litter chair/table for instrumented human subjects. Blood pooling (cardiovascular alteration) will be studied in X-49; an evaluation of the effects of motion sickness (oculogyral effects of rotation) will be studied in X-51. X-66 uses a gimbaled platform and bullfrog specimens to measure otolith output adaptation to zero-g.



Control/display panels for the racks are illustrated in Figures 4-4 and 4-5. Experiment equipment locations and side elevations are shown in Figure 4-6. Also, each rack-installed unit is identified by the end item number for the experiment. End item numbers were assigned in the preparation of GPREDP's for each experiment. Since GPREDP's are only on an experiment basis, common usage items were assigned arbitrarily to individual experiments even though used by a number of other experiments. (The GPREDP's for Life Sciences payload are contained in Appendix C.) Spacelab power (EPSP), data (RAU), and communication (ICRS) installations for each rack are also indicated in the figure.

Figure 4-7 shows the installation design concepts of all floor-mounted equipment. The major installation consists of two monkey pods and their base assembly. The monkey pods house two primates for experiment 76 and includes environmental control and life support functions. The base assembly houses automatic feed and water systems, breathing gas control, pressure control, all associated plumbing, and wiring and consumables. A supporting pump assembly is attached below the floor to provide pull-down capability for racks 11 and 12 and floor-installed equipment. The assembly consists of five pumps and related plumbing and control circuitry.

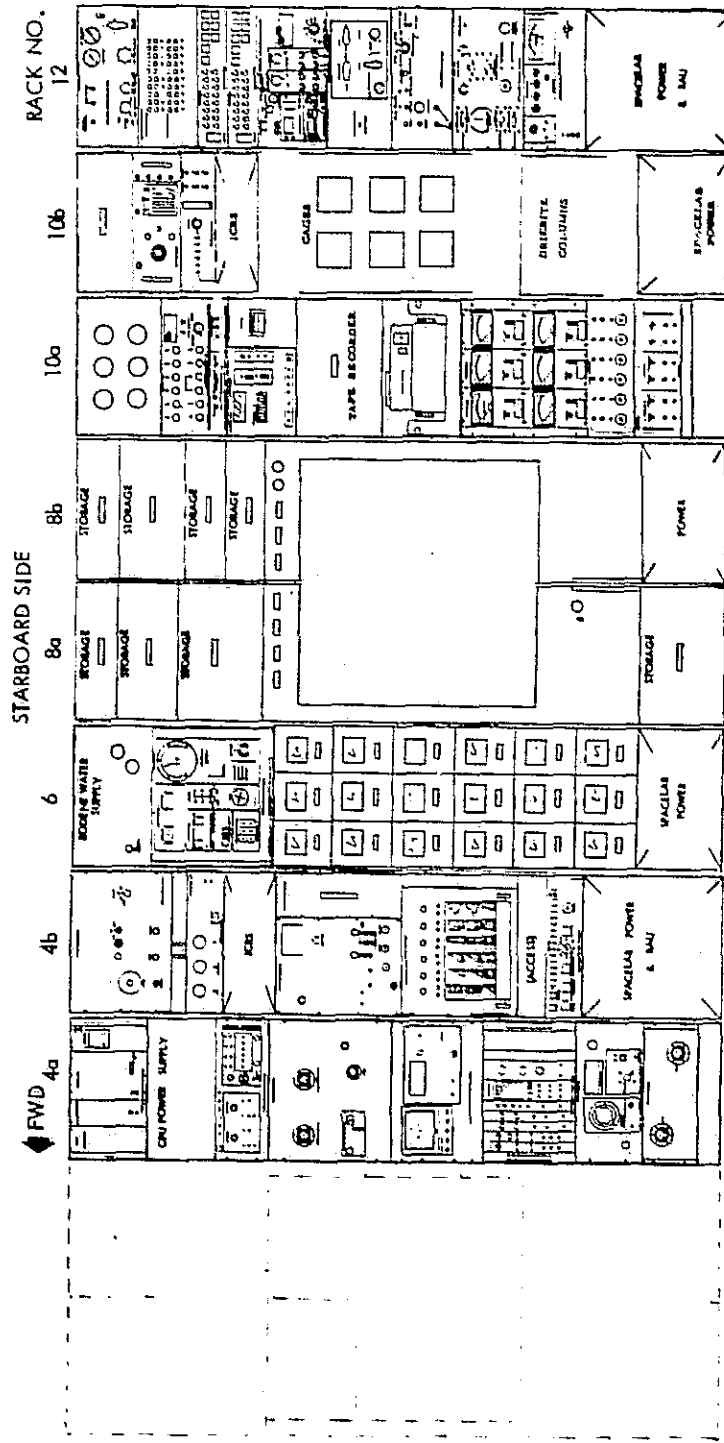
The rotating-tilting base assembly is attached to the floor and wired to the control panel of rack 3. The base is used during flight by attaching either a folding litter chair (X-49 and X-51) or a gimbaled frog platform (X-66). A microscope, with an articulated arm assembly is used with the gimbaled platform, and is installed on-orbit by attachment to a bracket which must be installed on an upper rack hard point. The chair, platform, and microscope assemblies are stowed for launch and reentry.

One other floor installation is required, consisting of a mechanical base plate with no functional interface. On-orbit, this plate is used for connecting the oscillating monkey "chair" described previously.

Orbiter-Installed Equipment

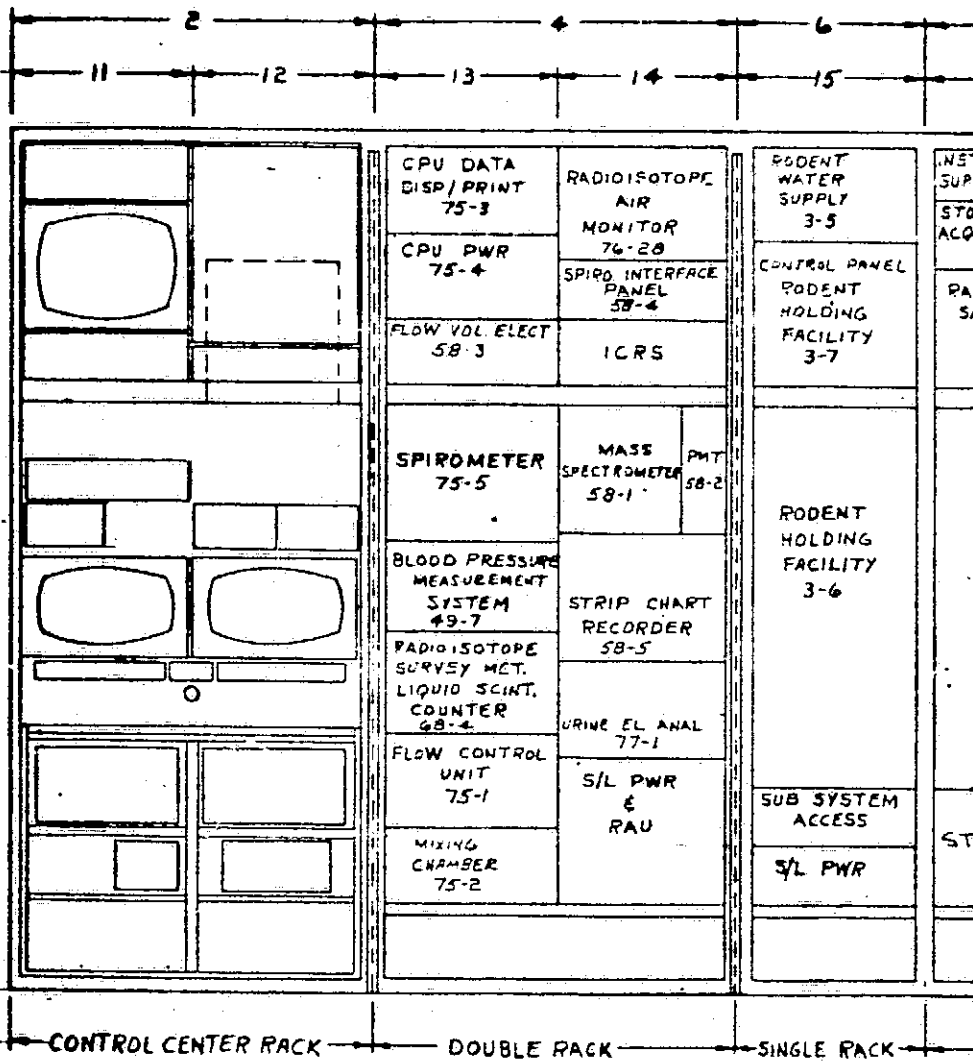
The experiment equipment installed in the Spacelab module is basically self-sufficient (with Spacelab support equipment) and is operable only from within the module. Therefore, no aft flight deck controls and displays are required for module-mounted equipment. However, the standard Spacelab CDMS installation will be included at the Payload Station. In addition, one Life Sciences experiment is designed to be located in the Orbiter as shown in Figure 4-8. This experiment, X-5, will measure the ability of individuals to regulate autonomic functions through the use of body sensor instruments. The subject will measure success in self-regulation from data displayed on the Spacelab CRT.

An added Life Sciences instrument, a doppler ultrasonic flowmeter, is installed in the avionics bay for use in measuring temporal arterial flow of an instrumented passenger during ascent and entry. This instrument is the same as installed in rack 3 for experiment X-49, and provides for a continuation of that experiment data. This installation is also shown in Figure 4-7.



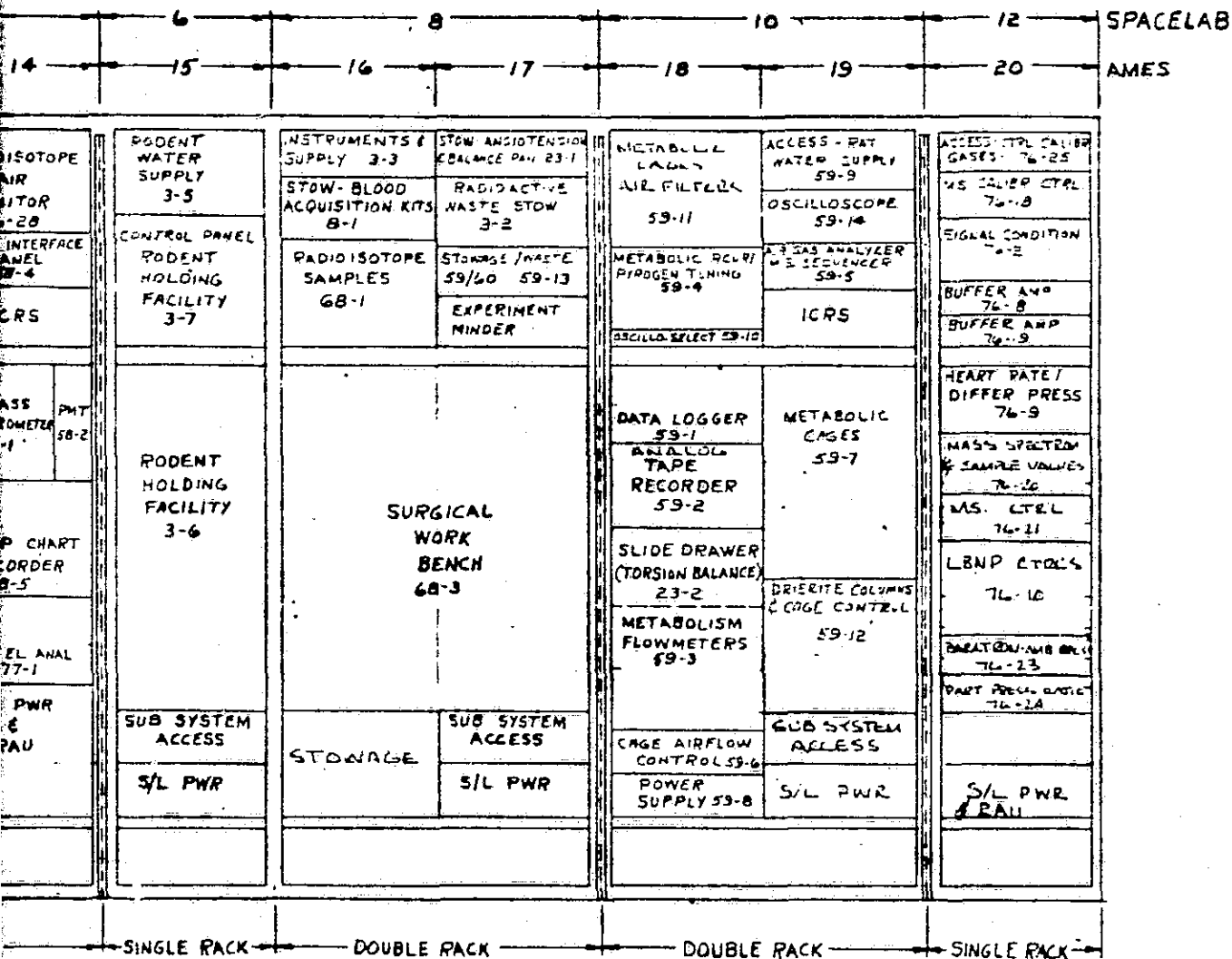
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Figure 4-4. Life Sciences Starboard Rack Installation

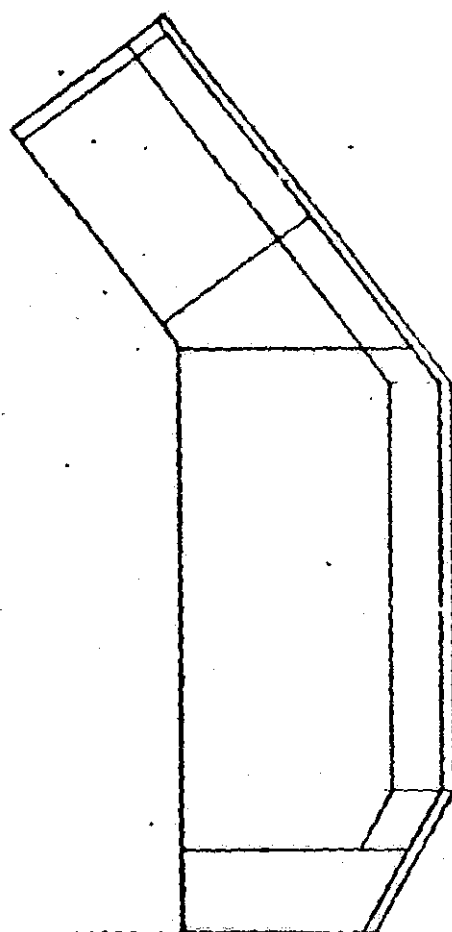


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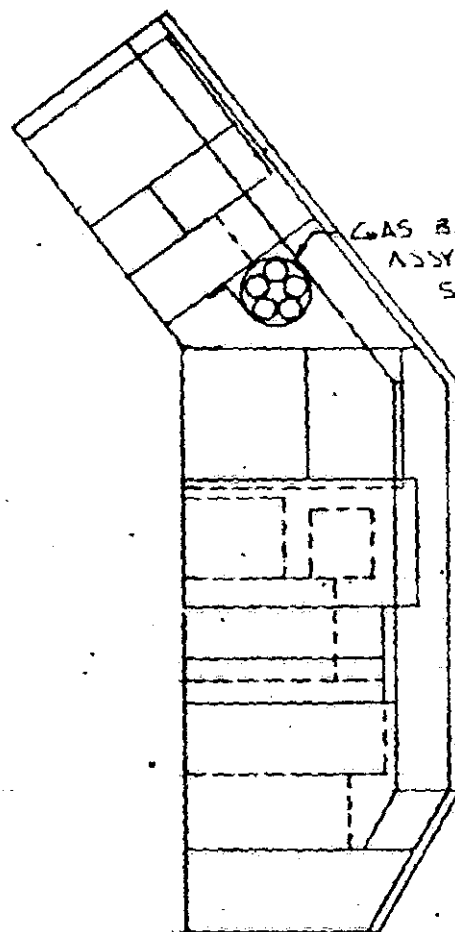
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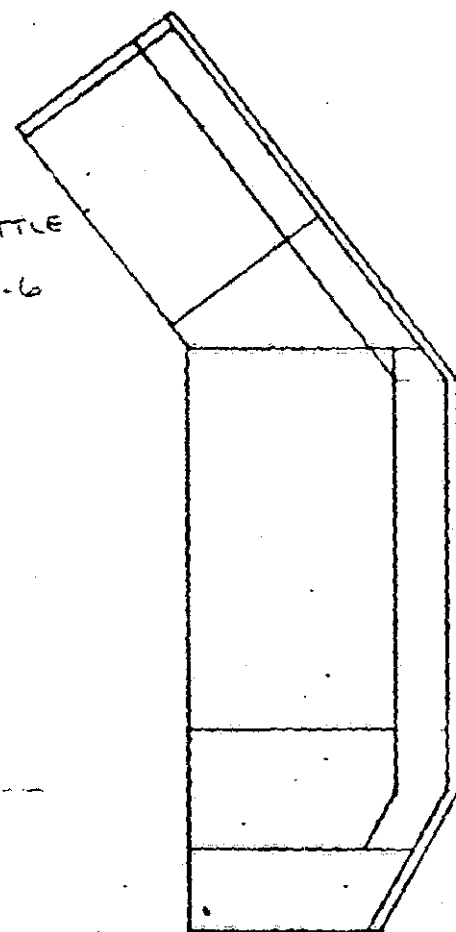


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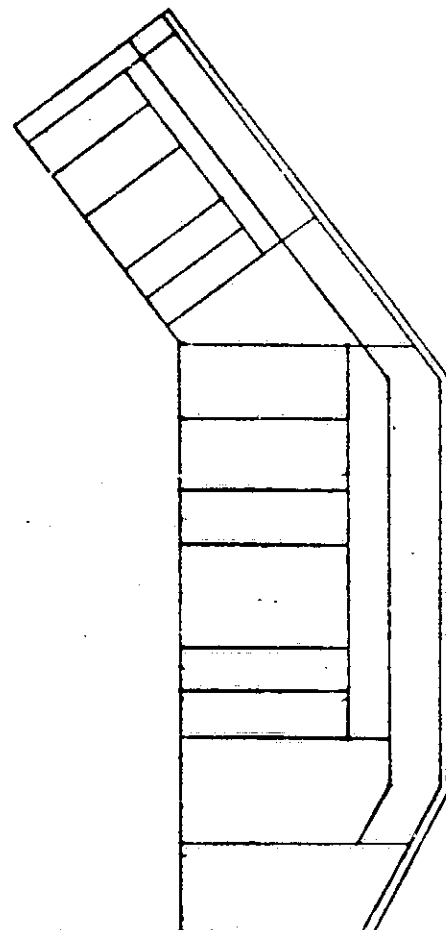
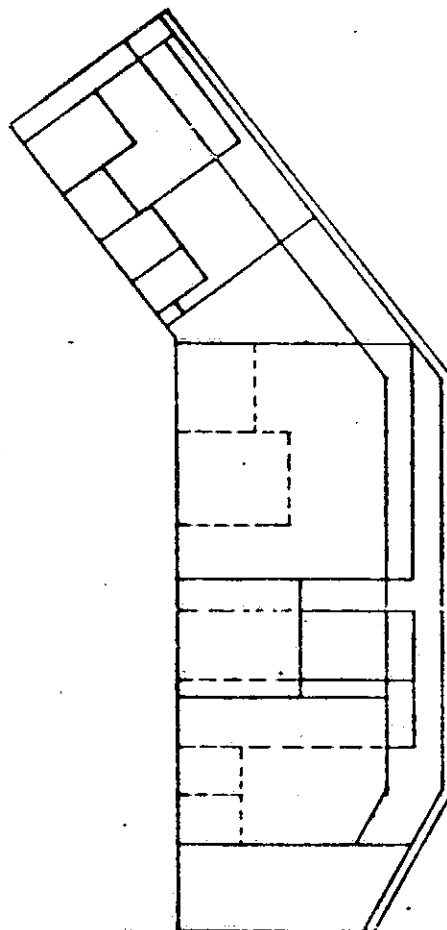
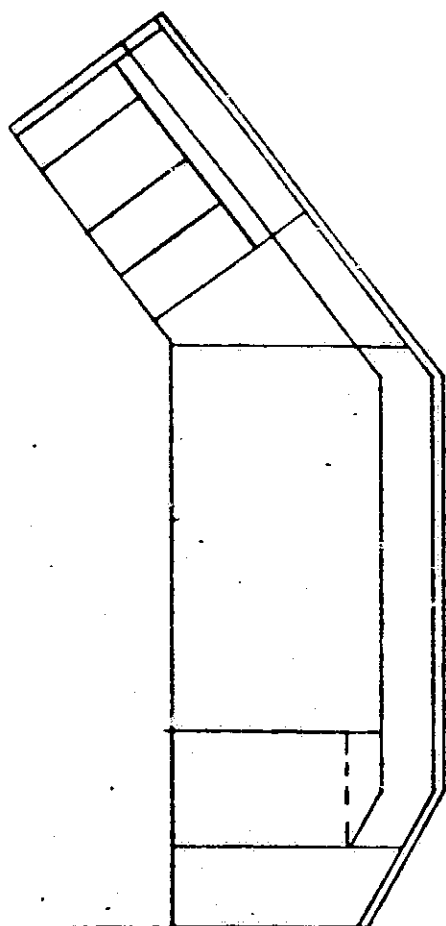
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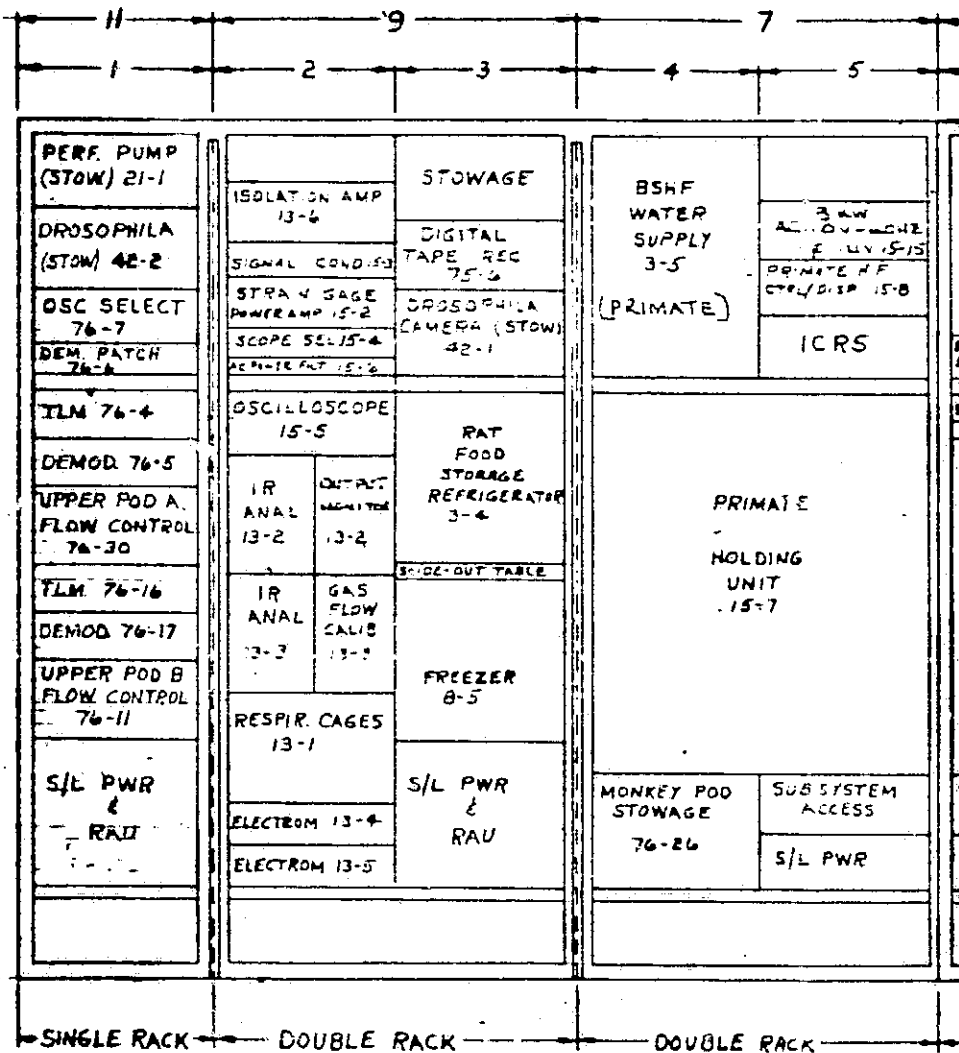
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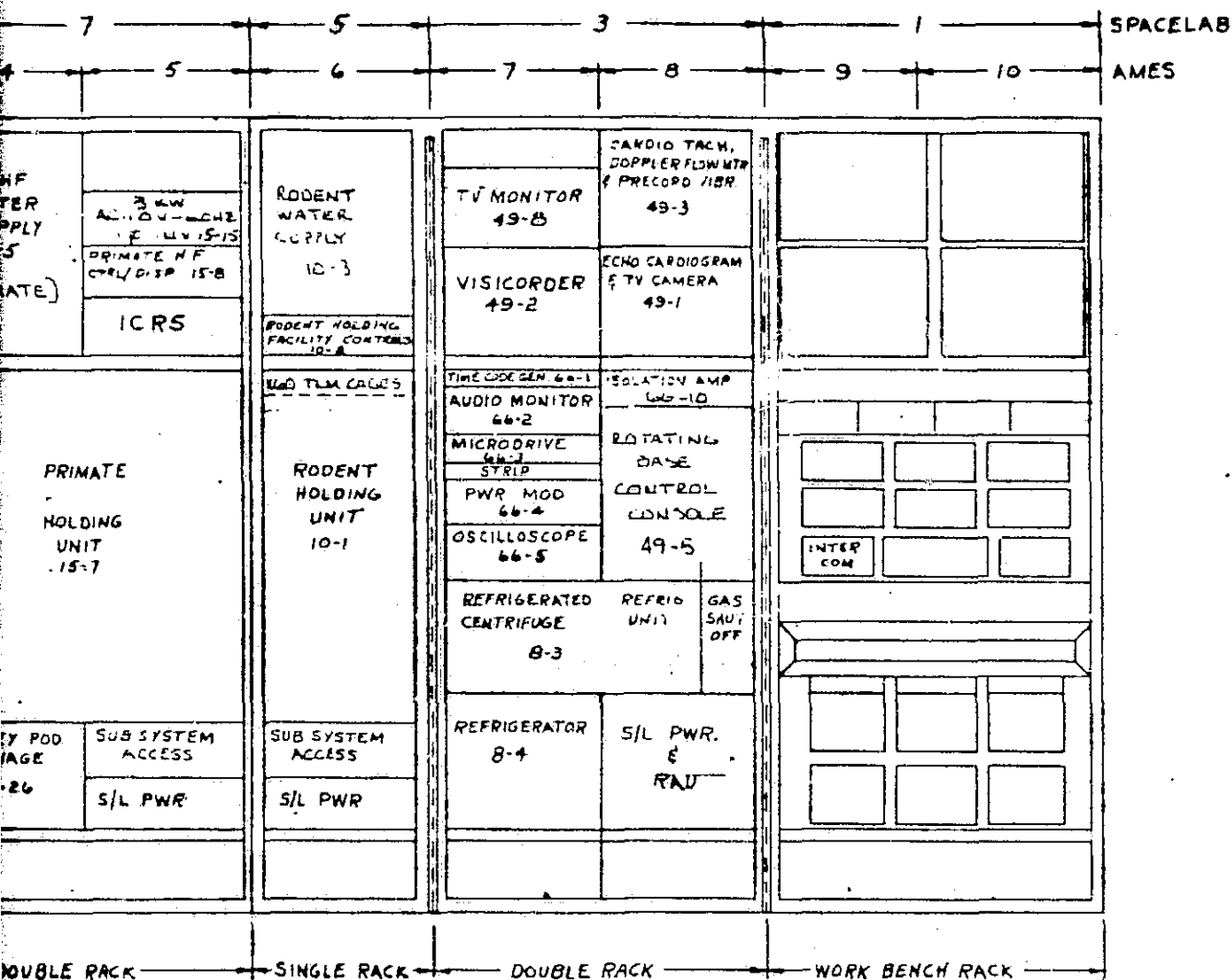
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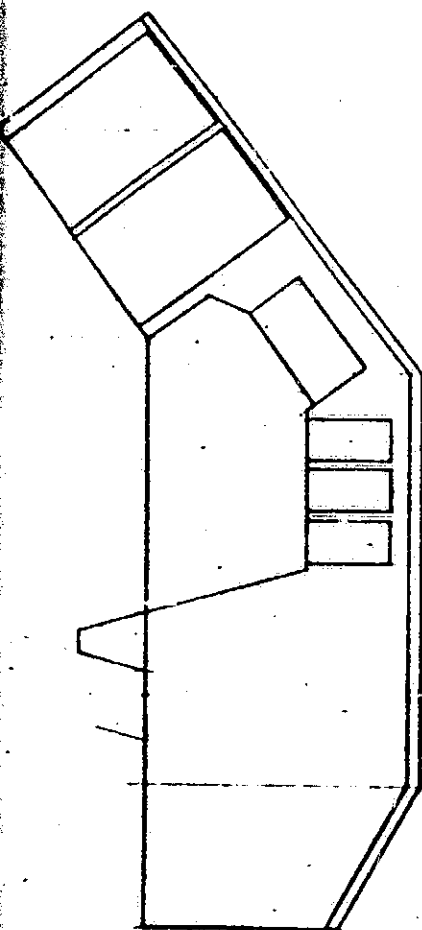


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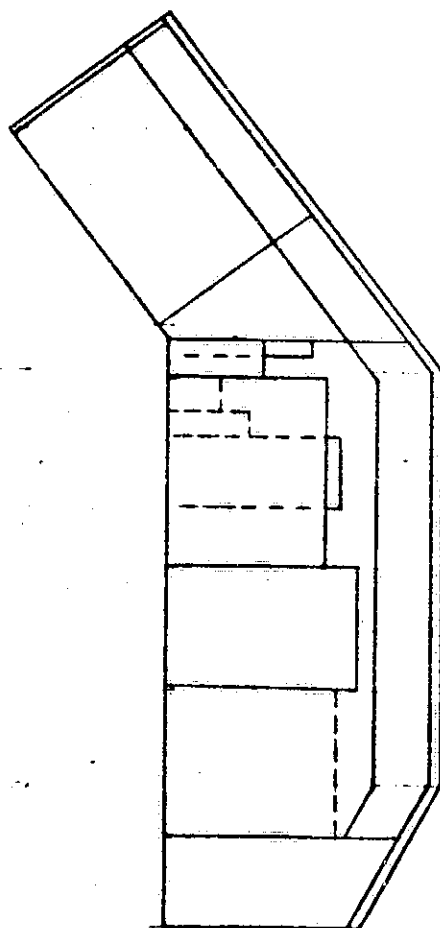
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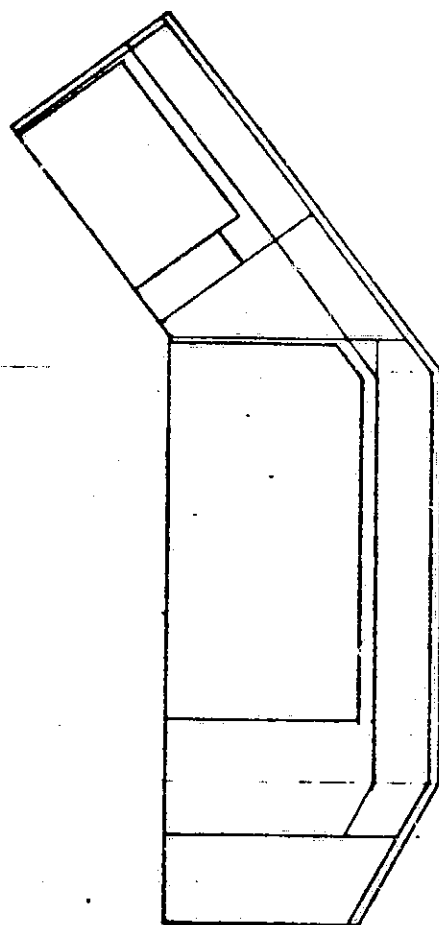
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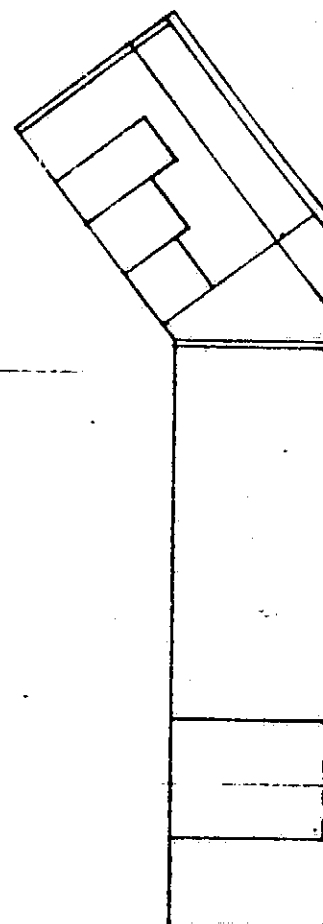
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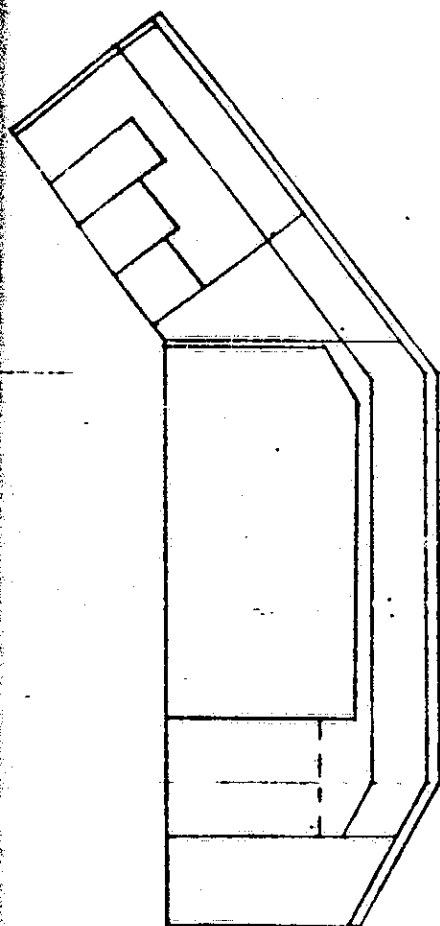


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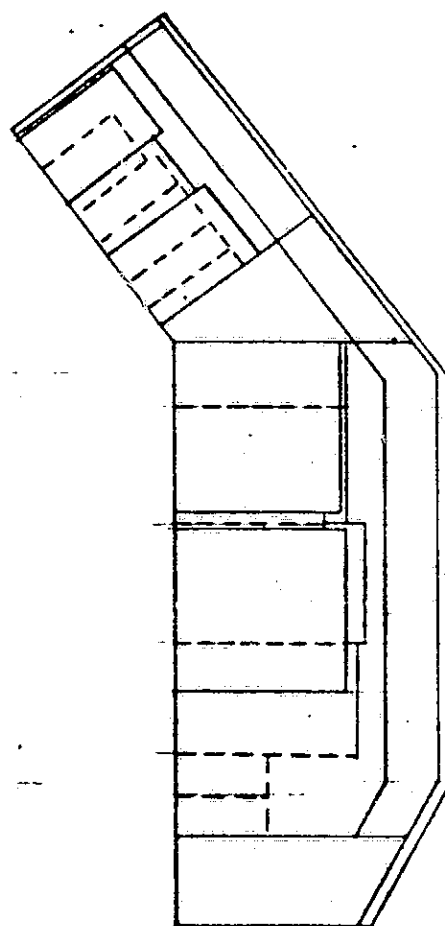
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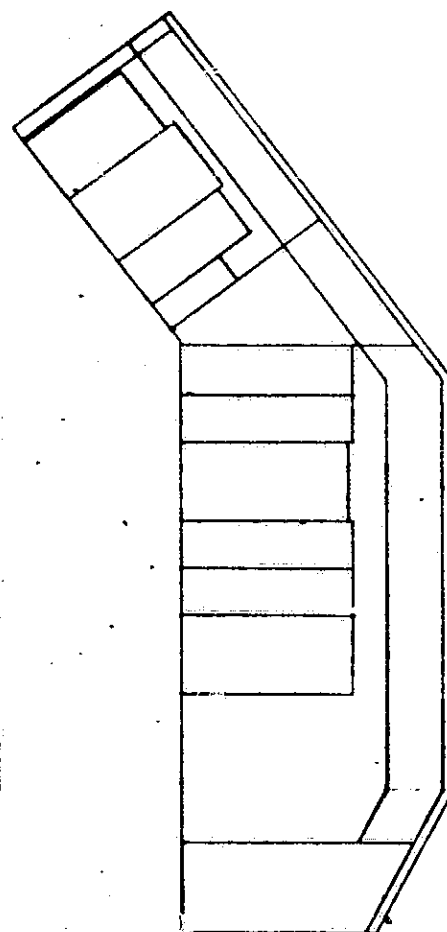
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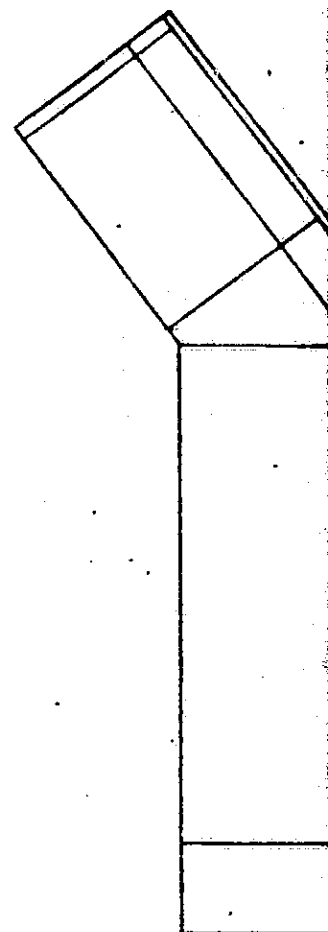
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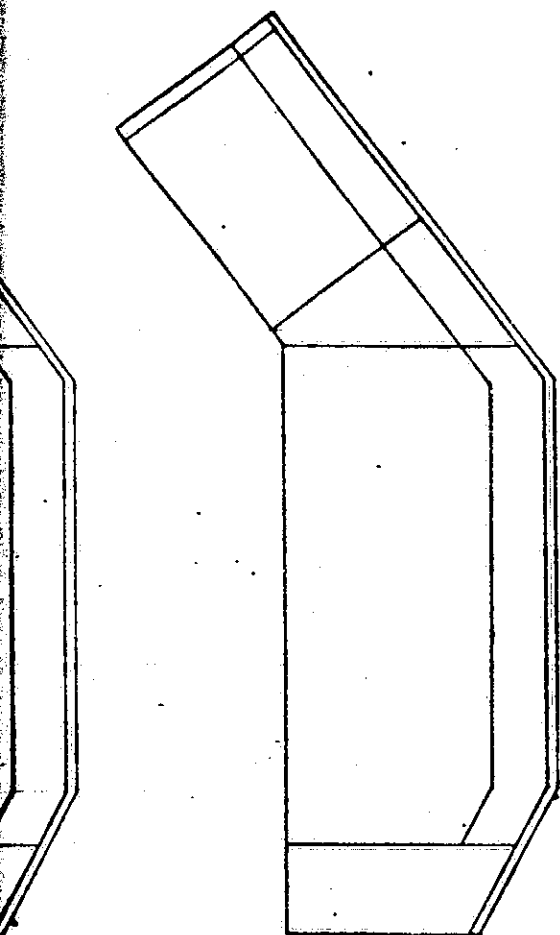
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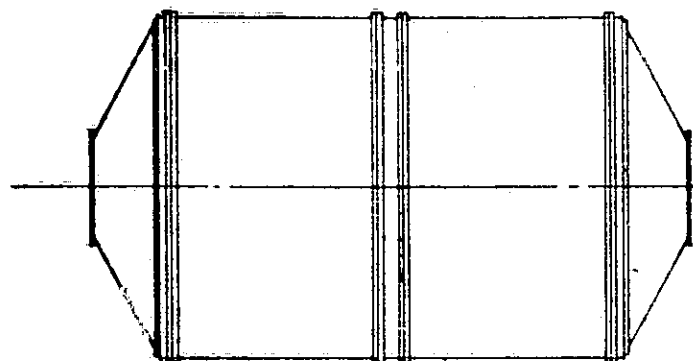
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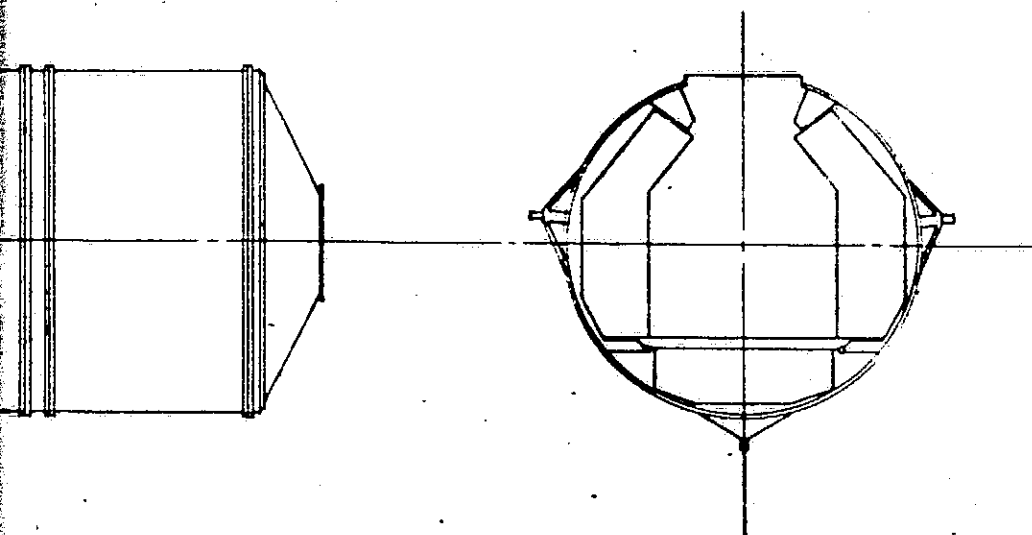


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LONG MODULE

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LONG MODULE SPACELAB

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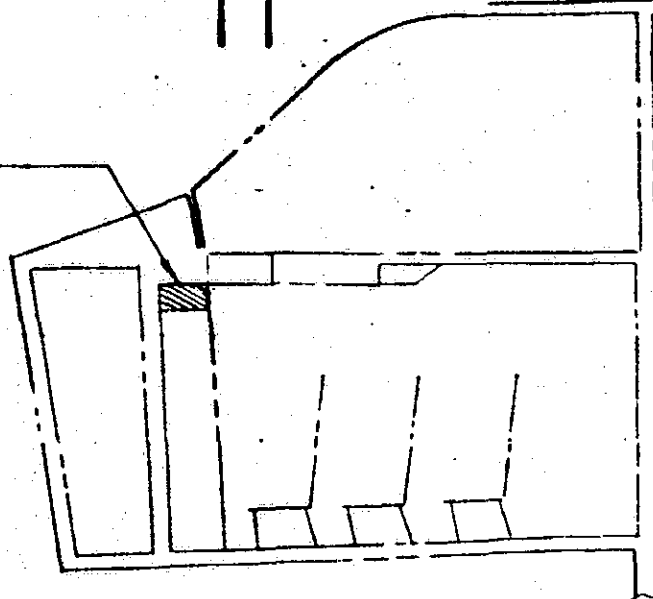
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Figure 4-6. Experiment Locations in the Racks

TITLE NUMBER DATE BY CHECKED BY APPROVED BY	ROCKWELL INTERNATIONAL CORPORATION SPACE DIVISION 1000 ROCKWELL AVENUE, TORRANCE, CALIF. 90503	REF ID: A78
SD 78-SR-0009-1	LIFE SCIENCES EXPERIMENTS	2528-1B

ULTRASONIC FLOW
METER (R/H)

49-6



PORT
SIDE

FEEDER/WATER SUPPLY (2) DELIVER POWER HP MODEL 6/2184 DC (3) SENSING & SIGNAL CONDITIONING UNIT 76-21	☐ PWR OUT	STORAGE: CAMERA ETC 76-32
WATER STORAGE FEEDER 76-14 USUAL TANK 76-14 WATER COOL UNIT (2) 18000 GALS 364 (2)		STORAGE MONKEY POD FOOD 76-29
BASE, POD B FAN MOTOR 76-18	POD'S INTERFACE PANEL 76-3	BASE, POD A FAN 76-15
TEMPERATURE MEASUREMENT 76-13	☐ PWR OUT	
WATER COOL FILTER 76-29		

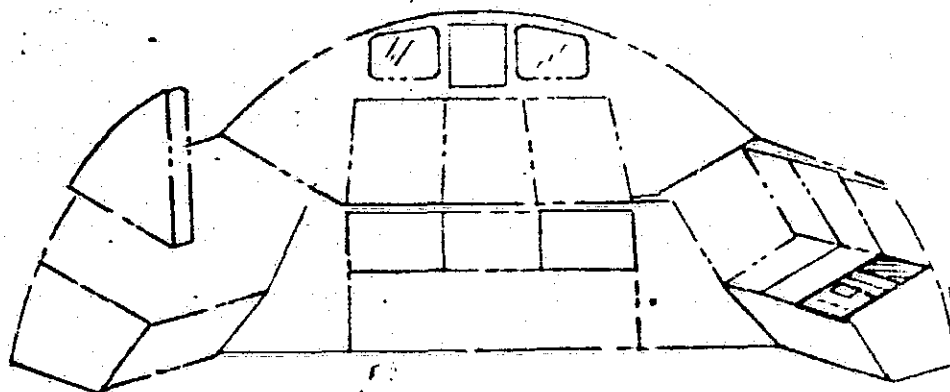
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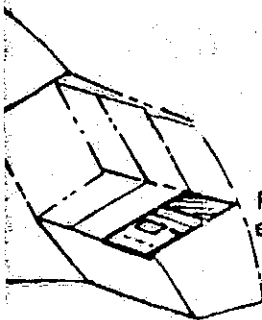
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MONKEY POD INSTAL X76

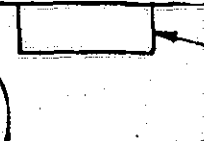
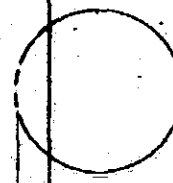
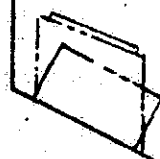
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P5 INSTL
EXPERIM
END ITEM
C-1 THRU

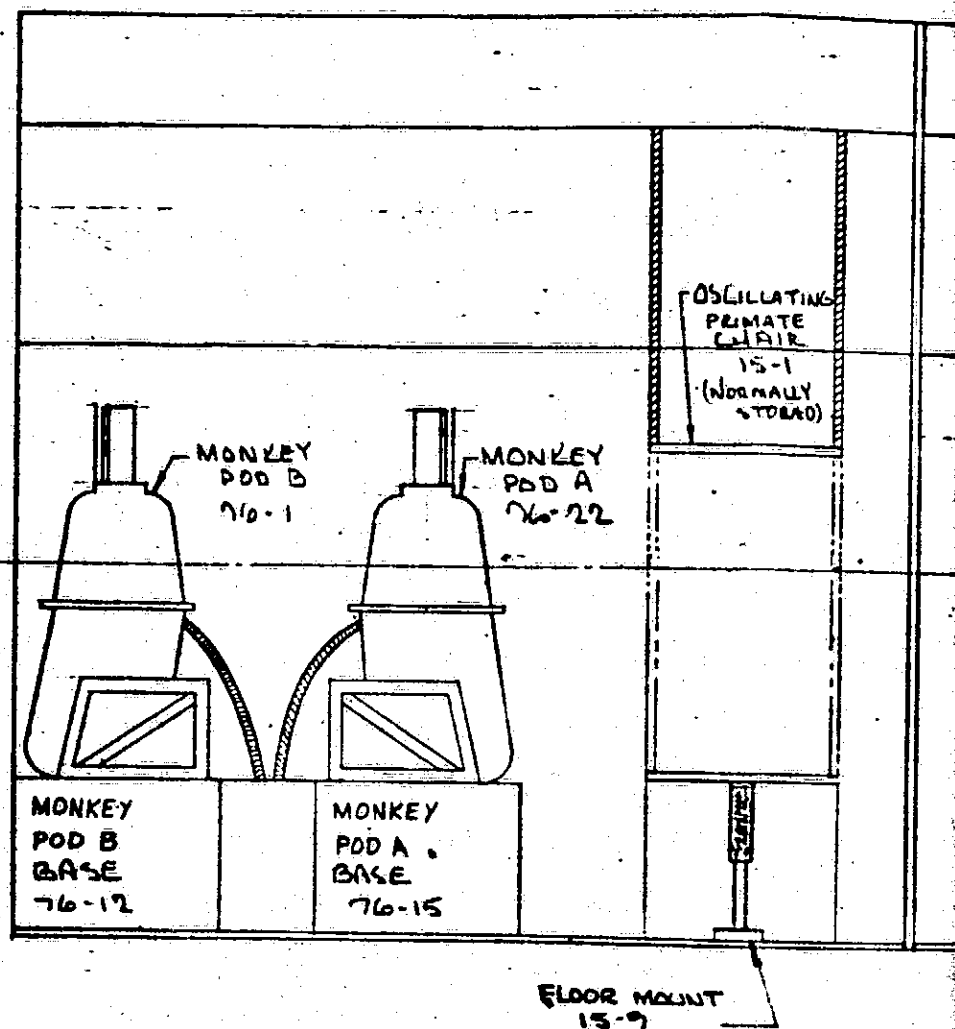
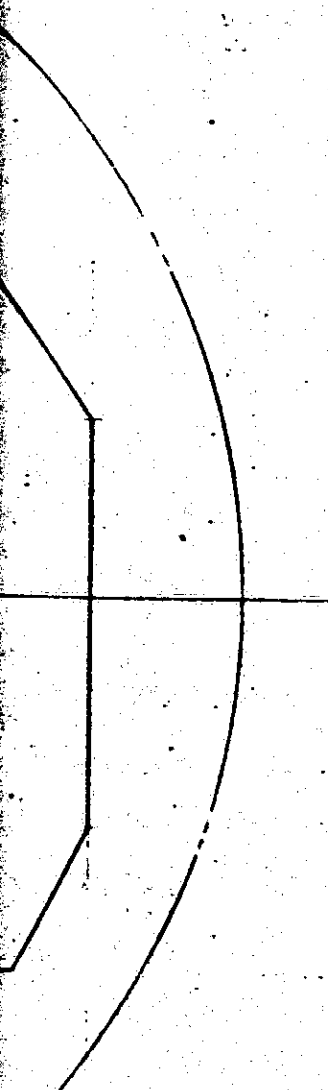


PS INSTL
EXPERIMENT X5
END ITEMS
C-1 THRU S-6



76-33
PUMP INSTL
• PDB A PUM
• PDB B PUM
• L&NP PUM
• VENT PUM
• MASS SPEC

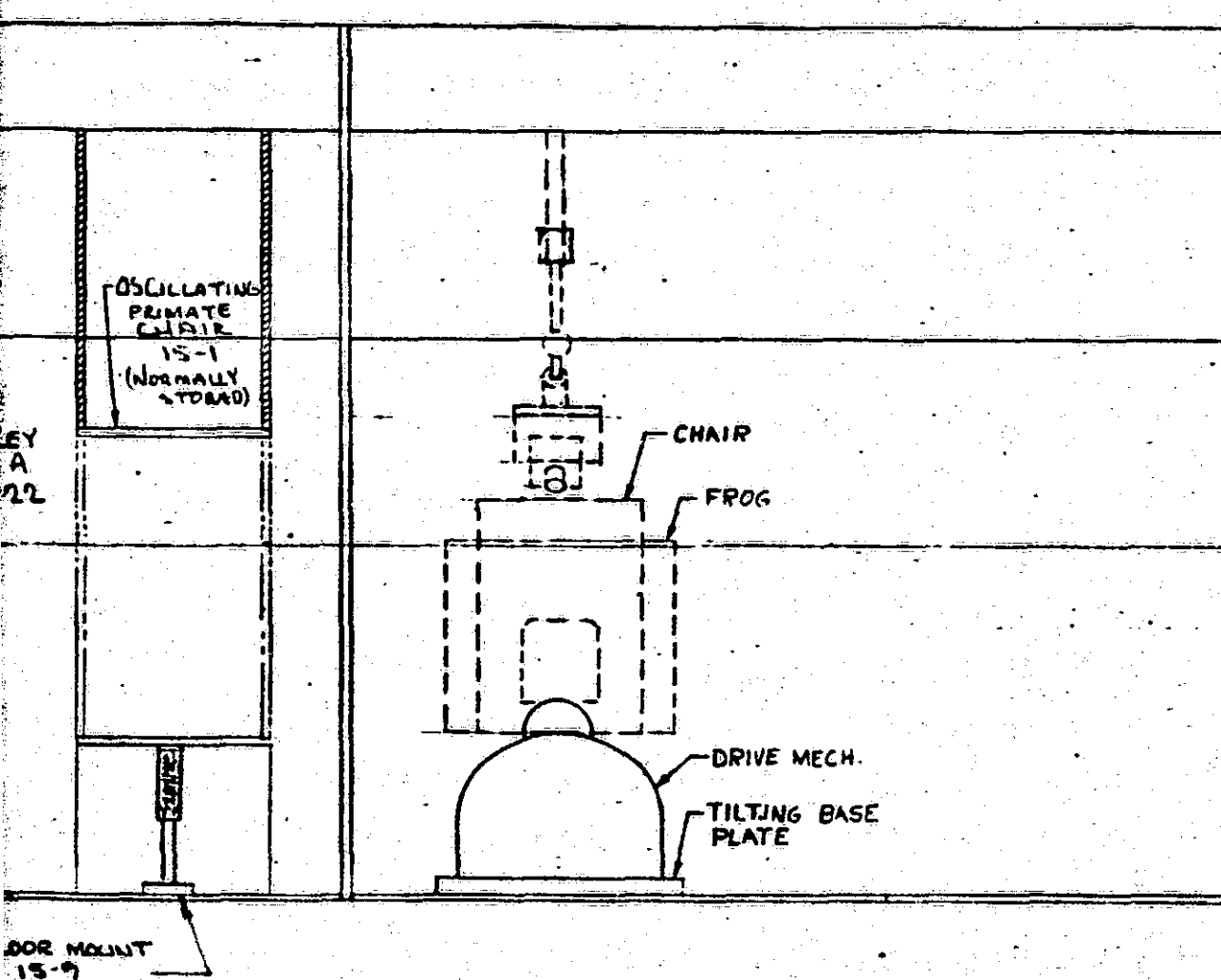
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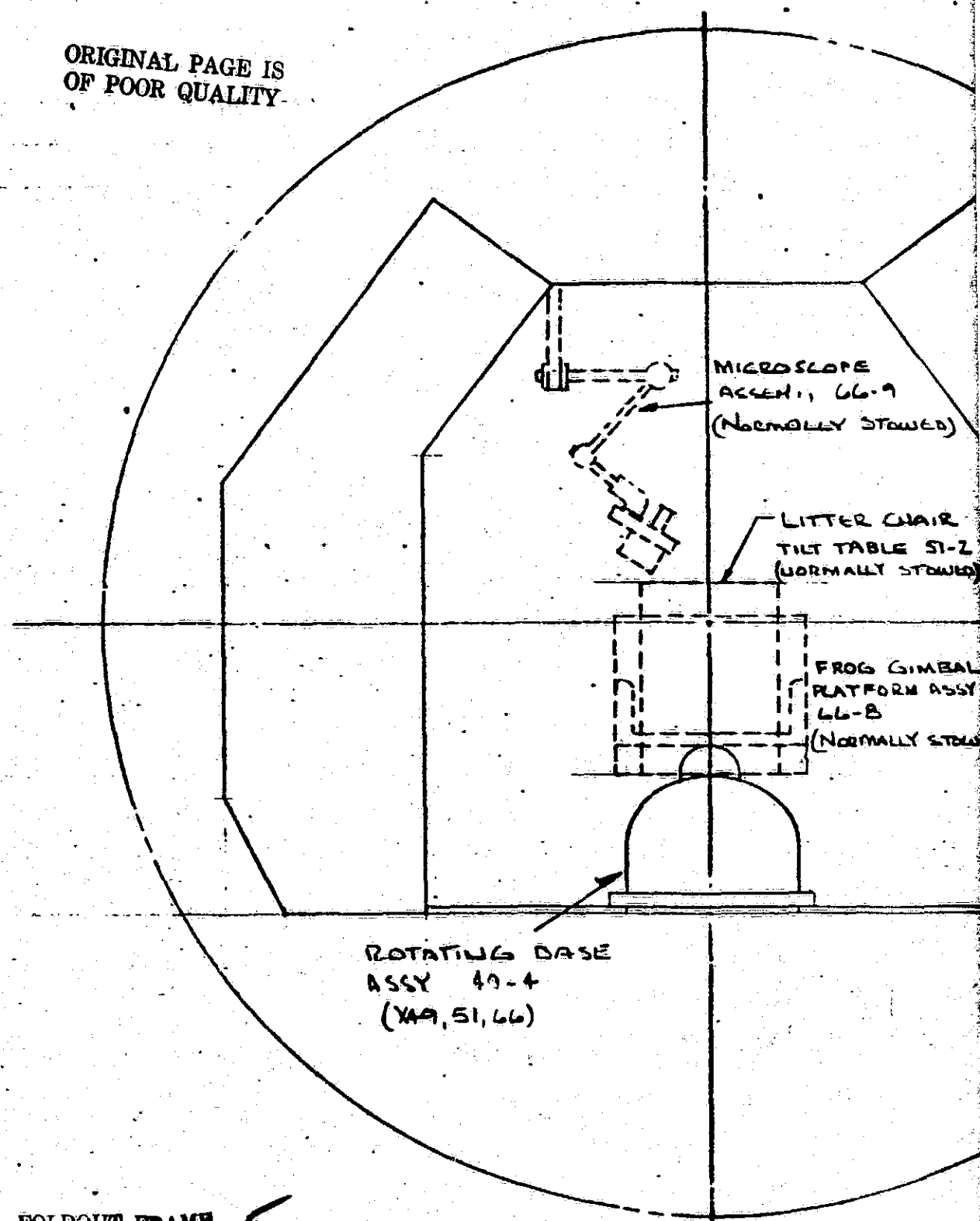
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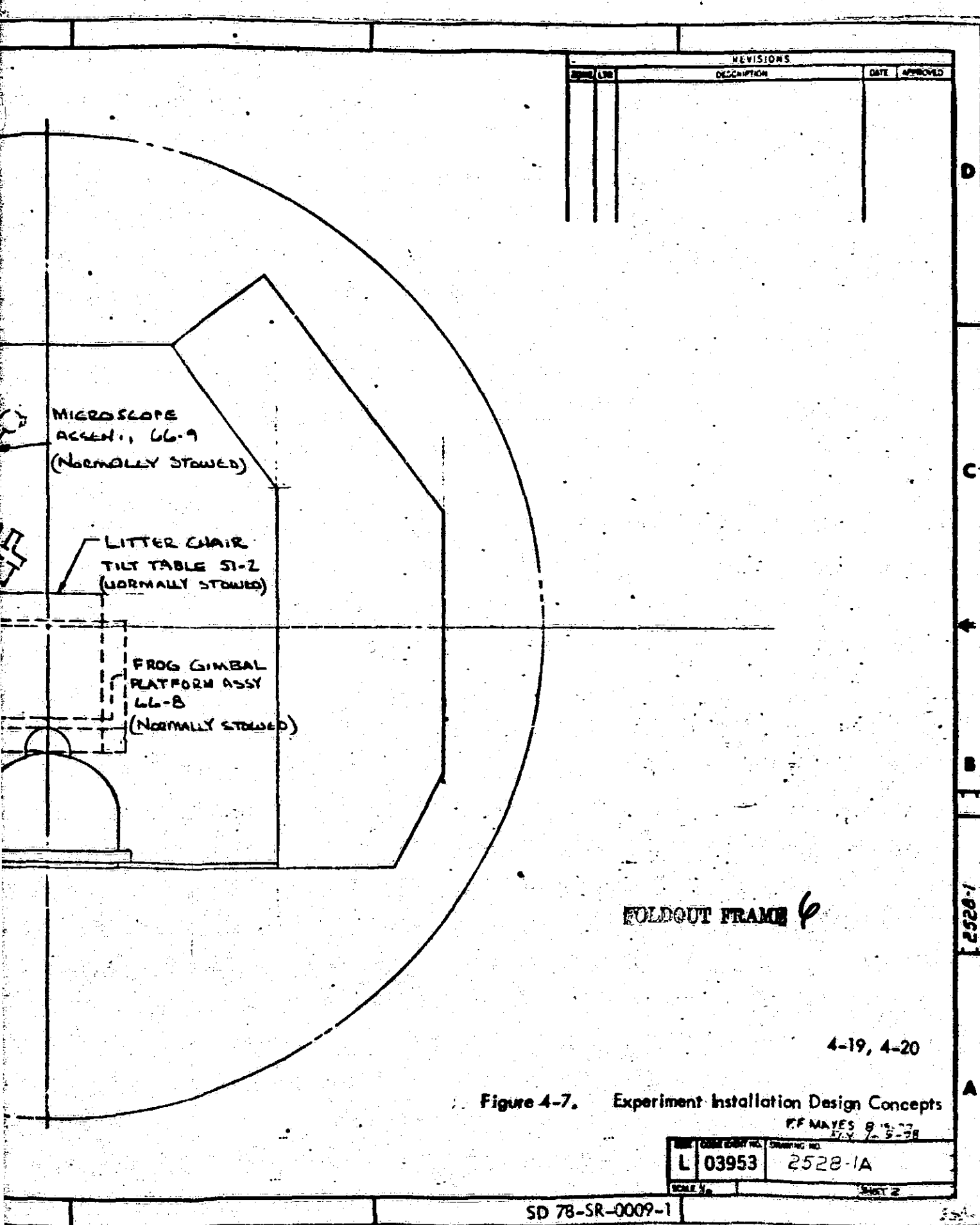
- 76-33
PUMP INSTL
- POD A PUMP
 - POD B PUMP
 - LEND PUMP
 - VENT PUMP
 - NAIK SPEC PUMP



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Figure 4-7. Experiment Installation Design Concepts

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SCALE 1/8"		SHEET 2	

2528-1

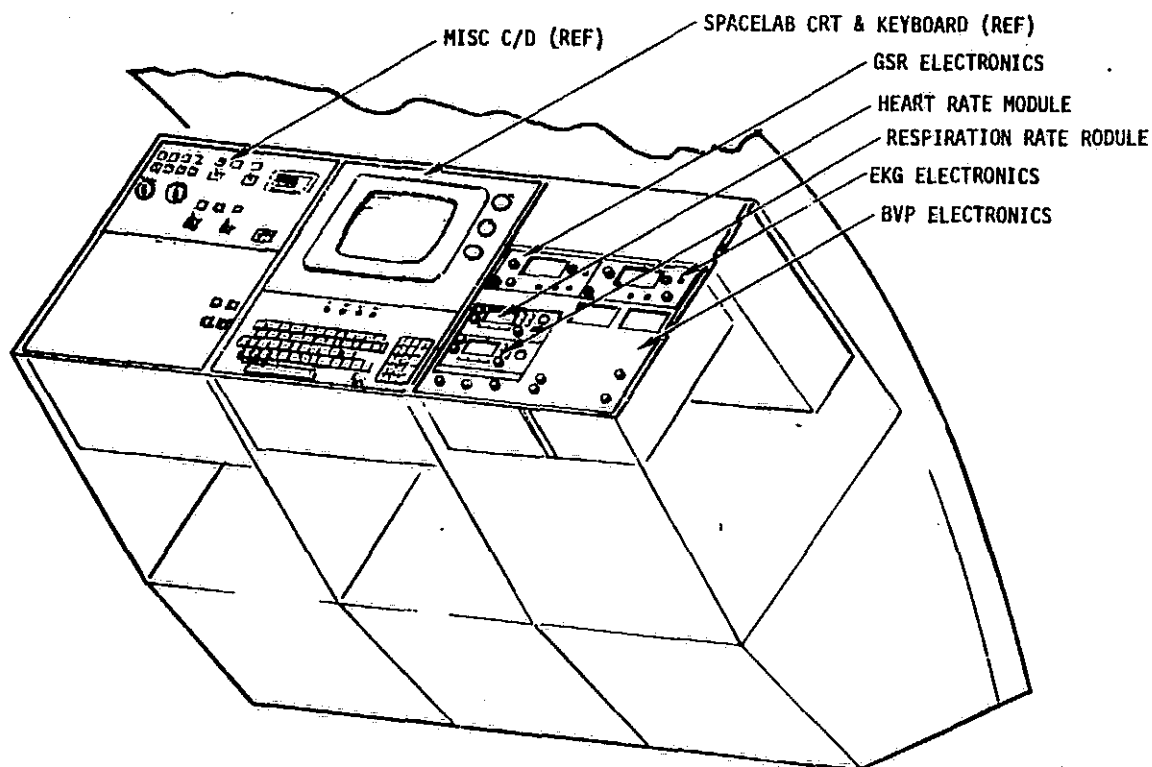


Figure 4-8. Life Sciences Payload Orbiter
Aft Flight Deck Arrangement

One additional Orbiter installation is required when primates and rodents are used as specimen. Their transportation cages are designed for attachment to the Orbiter mid-deck floor just aft of the forward avionics bay. By transporting the specimens in the cabin, later access during prelaunch, an earlier access after landing is possible. Direct monitoring can also be achieved by the payload specialists during boost and entry. After orbit insertion, the transport cages are moved into the Spacelab module, and the specimens are placed in their holding units.

Experiment and Spacelab Equipment Summary

A complete listing of experiment-provided end items is included in matrix form in Table 4-2. This table gives the location of the item (by rack number or other location), the name, and end item number. Rack numbers are listed by the Spacelab (S/L) number assignment and also, for reference, by numbers used in the Life Sciences (L/S) simulation.¹ The table also lists required Spacelab interface equipment, Experiment Power Switching Panel (EPSP), Remote Acquisition Unit (RAU), Intercom Remote Station (ICRS), Electrical Power Distribution Box (EPDB), and Center Aisle Connector Bracket (CACB).

¹"Life Sciences Spacelab Mission Development Test III", SE-SMD-III-062, JSC-11768, Feb. 1977 and SE-SMD-III-063, JSC-11821, April 1977, NASA-JSC, Houston, Texas.



Table 4-2. Matrix, Life Sciences Equipment - Port Rack Installation

RACK		NAME	END ITEM	O T R	C O R E	EXPERIMENT NO.																			
5 /	L 5					3	5	8	10	11	12	13	15	21	23	27	39	42	49	51	58	59	60	66	68
11	1	STOWAGE - PERFUSION PUMP DROSOPHILA STOWAGE OSCILLOSCOPE (POD) SELECTOR DEMOMULATOR PATCH PANEL TELEMETRY TUNE/RECEIVER DEMOMULATOR UPPER POD A FLOW CONTROL TELEMETRY TUNE/RECEIVER DEMOMULATOR UPPER POD B FLOW CONTROL (SPACELAB - EPSF)	21-1 42-2 76-7 76-6 76-4 76-5 76-30 76-16 76-17 76-11 -							X					X										X X X X X
9	2	ISOLATION AMPLIFIER SIGNAL CONDITIONER STRAIN GAUGE PWR SUPPLY SCOPE SELECTOR A.C. POWER FILTER OSCILLOSCOPE IR ANALYZER/OUTPUT MONITOR - /GAS FLOW CALIB. RESPIRATORY CAGES VIBRATION REED ELECTROMETER	13-6 15-3 15-2 15-4 15-6 15-5 13-2 13-3 13-1 13-4 13-5							X X X X X															
	3	STOWAGE DIGITAL TAPE RECORDER DROSOPHILA CAMERA (STOW) REFRIGERATOR - RAT FOOD SLIDE TABLE FREEZER (SPACELAB - EPSF & RAU)	75-0 42-1 3-4 8-5 -			X	X	X	X	X	X	X	X	X	X			X	X		X				X
7	4 4/5	BSHF WATER SUPPLY STOWAGE - MONKEY PODS PRIMATE HOLDING UNIT	15-11 76-26 15-7		14/16					X				X											X
	5	BLANK A-C INVERTER - 60 HZ PRIMATE H.F. CTRLS/DISPL. (SPACELAB - ICRS - EPSF)	15-12 15-8 -			X	X	X		X X X				X		X		X	X		X			X	X
5	6	RODENT WATER SUPPLY RODENT H.F. CTRLS/DISPLAY RODENT HOLDING FACILITY (SPACELAB - EPSF)	10-3 10-2 10-1 -		14/16			Y		X X 6			X X 20					X X 5	X X 6		X X 14				
3	7	TV MONITOR OSCILLOGRAPHIC RECORDER TIME CODE GENERATOR AUDIO MONITOR MICRODRIVE POWER MODULE & STRIP OSCILLOSCOPE REFRIGERATED CENTRIF. REFRIGERATOR	49-8 49-2 66-1 66-2 66-3 66-4 66-5 5-3,1 8-4													X X									
	8	CARDIOTAC, FLOW MTR, PR. VIBR. ECHOGRAPHIC & TV CAMERA ISOLATION AMPLIFIER ROTATING BASE CONTROL CONSOLE OSC. RECORD & CHAIR CTRL CENTRIF. REFRIG. & GAS SHUT, (SPACELAB - EPSF & RAU)	49-3 49-1 66-10 49-5 49-5 8-3,2 -													X X X X									
RACK		NAME	END ITEM	O T R	C O R E	EXPERIMENT NO.																			
5 /	L 5					3	5	8	10	11	12	13	15	21	23	27	39	42	49	51	58	59	60	66	68



Table 4-2. Matrix, Life Sciences Equipment - Starboard Racks Installation
(continued)

RACK		NAME	END ITEM	O T R	C O R E	EXPERIMENT																					
5/L	1/5					3	5	8	10	11	12	13	15	21	23	27	39	42	49	51	58	59	60	66	68	74	75
4	13	CPU DATA REDUCT. & PRINTER	75-3	1																						X	
		(GAS BOTTLE ASSY) - BEHIND BACK	58-6																							X	
		CPU POWER SUPPLY	75-4	1																						X	
		FLOW-VOLUME ELECTRONICS	58-3																							X	
		SPIROMETER	75-5	1																						X	
		BLOOD PRESS. MEAS. SYST. (BPMS)	49-7	1																							
		RADIO ISOTOPE SURV. MET. LIQ. SCIN.	68-4		X																						
		FLOW CONTROL UNIT	75-1	8																							
		MIXING CHAMBER	75-2																								
		RADIO ISOTOPE AIR MONITOR	76-28		X	X					X													X		X	
		INTERFACE PANEL	58-4	1																					X		
		(SPACELAB ICRS)	-																								
		MASS SPECTROMETER	58-1																							X	
		PNEUMOTACHOMETER	58-2																								
		STRIP CHART RECORDER	58-5																								
		URINE ELECTROLITE ANALYZER	77-1																								X
		(SPACELAB EPSP & RAU)	-																								
6	15	RODENT WATER SUPPLY	3-5				X			X	X			X	X												
		RODENT HF CONT./DISPLAY	3-7				X								X	X											
		RODENT HOLDING FACILITY	3-6				6				6	20			25	24											
		(SPACELAB-EPSP)	-																								
	16	INSTRUMENTS/SUPPLIES	3-3			X																					
		STOWAGE BLOOD ACQ. KITS	8-1						X	X															X	X	
		RADIO ISOTOPE SAMPLES	68-1																						X		
		SURGICAL WORKBENCH	68-3		X	X	X	X	X	X	X	X	X	X	X	X	X							X	X		
	17	STOWAGE ANGIO. & BALANCE PAN	23-1											X	X												
		STOWAGE - RADIOACTIVE WASTE	3-2				X																				
		STOWAGE - WASTE	59-13																								
		(SPACELAB-EPSP)	-																								
10	18	METABOLIC CAGE AIR FILTERS	59-11																								
		METABOLIC RCVR/PYKOGEN TUNING	59-4																								
		OSCILLOSCOPE SELECTOR	59-10																								
		DATA LOGGER	59-1																								
		TAPE RECORDER-ANALOG	59-2																								
	19	TORSION BALANCE (SLIDE)	23-2																								
		METABOLISM FLOW METERS	59-3																								
		CAGE AIR FLOW CONTROL	59-6																								
		POWER SUPPLY	59-8																								
	20	RAT WATER SUPPLY/ACCESS	59-9																								
		OSCILLOSCOPE	59-14																								
		AIR (GAS) ANALYZER/M.S. SEQ.	59-5																								
		(SPACELAB - ICRS)	-																								
12		METABOLIC CAGES	59-7			X								X													
		DRIERITE COLUMNS & CAGE CTRL.	59-12																								
		(SPACELAB-EPSP)	-																								
		CTRL CALIBR. GASES	76-25																								
		M.S. CALIBRATION CONTROL	76-18																								
		SIGNAL CONDITIONER	76-2																								
		BUFFER AMPLIFIER	76-8																								
		BUFFER AMPLIFIER	76-19																								
		HEART RATE/DIFFER. PRESSURE	76-9																								
		MASS SPECTROM. & SAMPLE VALVES	76-20																								
		MASS SPECTROMETER CONTROLS	76-21																								
		LBNP CONTROLS	75-10																								
		BARATRON-AMP. PRESSURE	76-23																								
		PART. PRESS. RATIO COMPUTER	76-24																								
		(SPACELAB-EPSP & RAU)	-																								
RACK		NAME	END ITEM	O T R	C O R E	EXPERIMENT																					
5/L	1/5					3	5	8	10	11	12	13	15	21	23	27	39	42	49	51	58	59	60	66	68	74	75



Table 4-2. Matrix, Life Sciences Equipment - Non-Rack Installed (continued)

LOCATION	NAME	END ITEM NO.	O T R NO.	C O R E	EXPERIMENT NO.																							
					3	5	8	10	11	12	13	15	21	23	27	39	42	49	51	58	59	60	66	68	74	75	76	77
END AISLE	FROG GIMBAL PLATFORM (STOW)	66-8																										
"	MONKEY PODS (A&B)	76-122																										
"	X-15 FLOOR MOUNT	15-9																										
"	ROTATING BASE/ASSEMBLY	49-4																										
OMD	RODENT TRANSPORTERS	3-1	18		X			X	X	X	X		X	X	X				X	X								
"	PRIMATE TRANSPORTERS	15-10	18																									
OVHD	HEMATOCRIT CENTRIFUGE (STOW)	8-2					X								X												X	
REFRIG. AISLE	FROG-HOLDING FACILITY	66-7																										
"	MICROSCOPE-ARM MOUNT (STOWED)	66-9																										
"	MONKEY OSCILL. PLAT. & ACCEL. (STOW)	15-1											X															
OAFD	RESPIRATION RATE MODULE	5-1																										
"	GALVANIC SKIN RESPONSE MOD.	5-2						X																				
"	ELECTROMYOGRAPH MODULE	5-3						X																				
"	BLOOD VOLUME PULSE ELEX.	5-4						X																				
"	HEART RATE MODULE	5-5						X																				
"	STOWAGE DRAWER	5-6						X																				
ORB, MID-DEK	ULTRASONIC (DOPPLER) FLOW METER	49-6																										
STOW	MICROSCOPE	68-2																										
"	MATING CAGE	68-5																										
POD ASSY.	TEMPERATURE MULTIPLEXER	76-13																										
"	BASE, POD A	76-15																									X	
"	BASE, POD B	76-12																									X	
"	PODS INTERFACE PANEL	76-3																									X	
"	MONKEY POD FOOD DRAWER	76-27																									X	
"	H2O COLLECTION/FILTER ASSY	76-29																									X	
"	FEEDER/WATER SUPL. SIGN. CONDIT.	76-31																									X	
"	CAMERA DRAWER, MONKEY POD	76-32																									X	
"	WATER STORAGE DRAWER	76-14																									X	
STOW	HAND HELD VOICE RECORDER	51-1																									X	
STOW	ELECTRODES & AMPLIFIER-STOWED	66-6																									X	
STOW	TILT TABLE/LITTER CHAIR	51-2																									X	
STOW	TILT ANGLE TRANSDUCER	49-9																									X	
BELOW FLOOR	PUMP ASSEMBLY	76-33																									X	
	(SPACELAB - EPDS & CAC B)	-																										

The columns OTR (Operational Test Requirements) and CORE (Common Operational Research Equipment) reflect most of the operational support equipment that will be common to multiple experiments on most of the Life Sciences payloads. The OTR numbers refer to SMD-III documentation. The balance of the matrix identifies the equipment used in each experiment, including sharing of common or unique items.

Functional Interfaces and Interconnections

Of the ten Spacelab racks for experiment equipment installation, four are primarily occupied by major common use items. These are: rodent holding units (racks 5 and 6), primate holding unit (rack 7), and surgical work bench (rack 8). The interface requirements for these racks were not considered sufficiently complex to require detailed functional schematics. Racks 5, 6, and 7 are essentially self-contained as regards command and control functions. Connection is required for power through the EPSP and air flow interconnection is required with the Spacelab system. The pressurized water supply is wholly contained within each rack, with the exception of an N₂ pressurant supply line. The surgical work bench installation similarly requires only power, N₂, and a vacuum reference interface. Finally, the right-hand side of rack 9 requires power connection only for the common use freezer and refrigerator.

The balance of the experiment equipment installations are shown in schematic diagram form for end item-to-end item interconnection. The equipment installed in double rack 3 and its adjacent floor segment is shown in Figure 4-9.

c-2

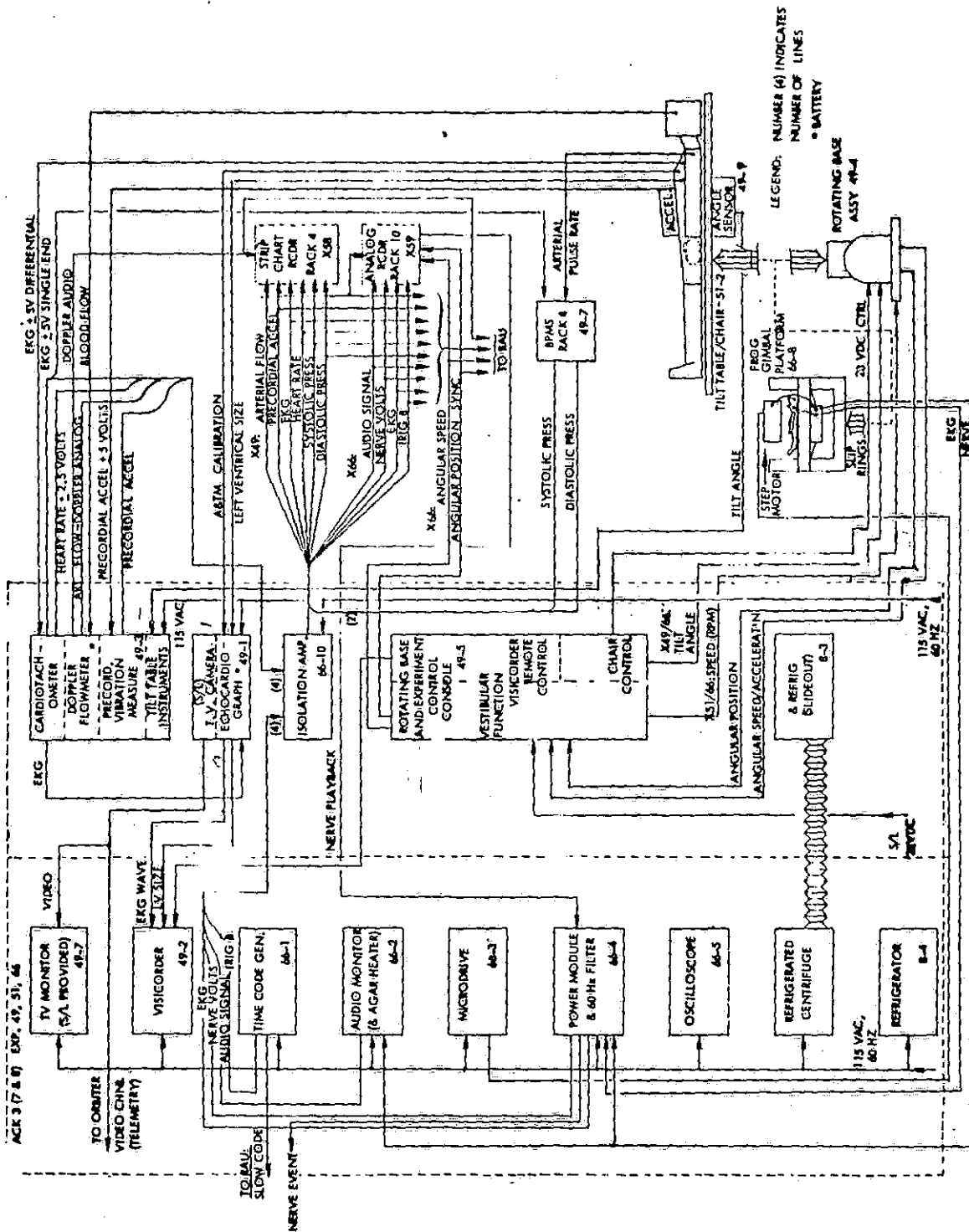


Figure 4-9. Experiment Equipment Interface Schematic for Rack 3 and Associated Floor Segment 2

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All end items are identified in their physical relationship in the double rack by name and number. The rack will require a center divider for all of the equipment except the refrigerated centrifuge. For this installation a modified arrangement is required to the Spacelab design to allow the unit to span the double rack width. The diagram identifies power and signal inputs and outputs to/from the rack, including those to the rotating base floor installation, to the in-flight operational setups including test subjects, to Spacelab equipment, and to other racks. Functional equipment in this installation is primarily associated with experiments X-49, X-51, and X-66, and common use refrigeration items.

Figure 4-10 provides equivalent information for double rack 4. In this case, no floor installation is associated with the experiments; however, on-orbit operations require connecting of a breathing mask from subjects to the rack-installed items. The end items in the rack require fluid (gas) interconnections, including an experiment-provided gas bottle assembly. Primary experiments in this rack are X-58 and X-75, plus the single X-77 end item and common-use radiation equipment.

The schematic for the double rack 9, Figure 4-11, which also includes fluid lines, requires front panel connection to the monkey "chair" as described earlier. The diagram only reflects Left Hand (L.H.) side of the rack because of the simple installation on the R.H. side described previously. The left side of the rack is dedicated to experiments X-13 and X-15.

The inter-rack plumbing complexity of rack 10 is shown in the schematic of Figure 4-12. One plumbing interface is to the adjacent rack 12. The other interface requires that plumbing be carried across the aisle under the floor to rack 11. This double rack is essentially dedicated to two experiments, X-59 and X-60.

The most complex installation for the Level IV integration involves two single racks, on opposite sides of Spacelab, and their attaching floor segment. The entire installation is devoted almost exclusively to experiment X-76. Figure 4-13 shows the total interconnection required including rack to floor, and under floor signal, power, and gas line interfaces. The monkey pods and their pedestal contain environmental control and life support elements as well as their intra-connecting wiring. The monkey pod assembly would be prepared at some level of effort of integration that precedes the Level IV activities. Only mechanical attachment and plumbing/wiring interface connection is performed in Level IV. The pump assembly will be attached to the underside of the floor during Level IV integration. Experiment X-42 Drosophila stowage is included to show the power connection required for day/night lighting.

These schematics furnished the material necessary to establish cabling and plumbing requirements. The functional schematics also serve as source data for defining verification requirements and interrack data interfaces. A summary of rack input/output signals is listed in Table 4-3.



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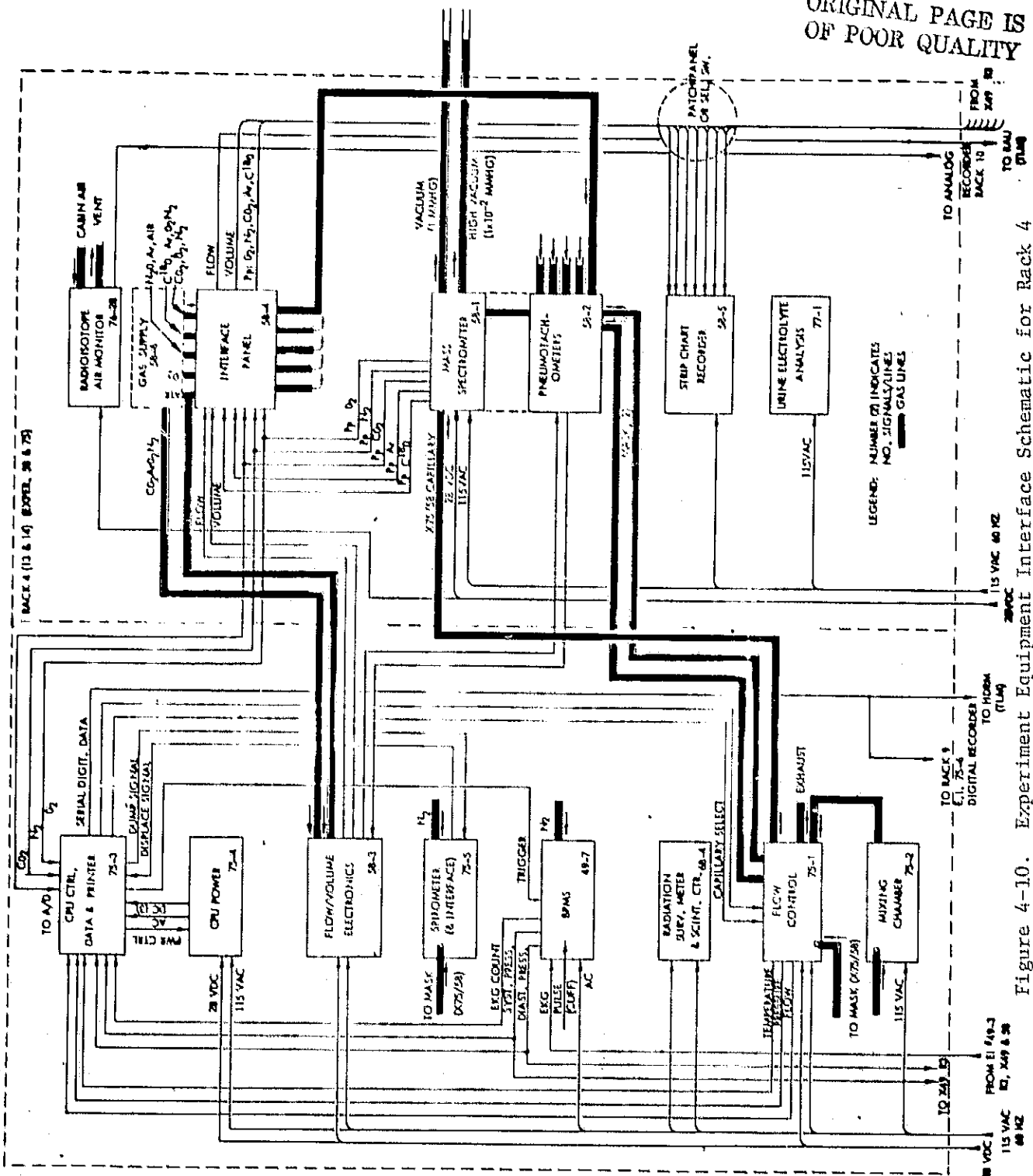


Figure 4-10. Experiment Equipment Interface Schematic for Rack 4

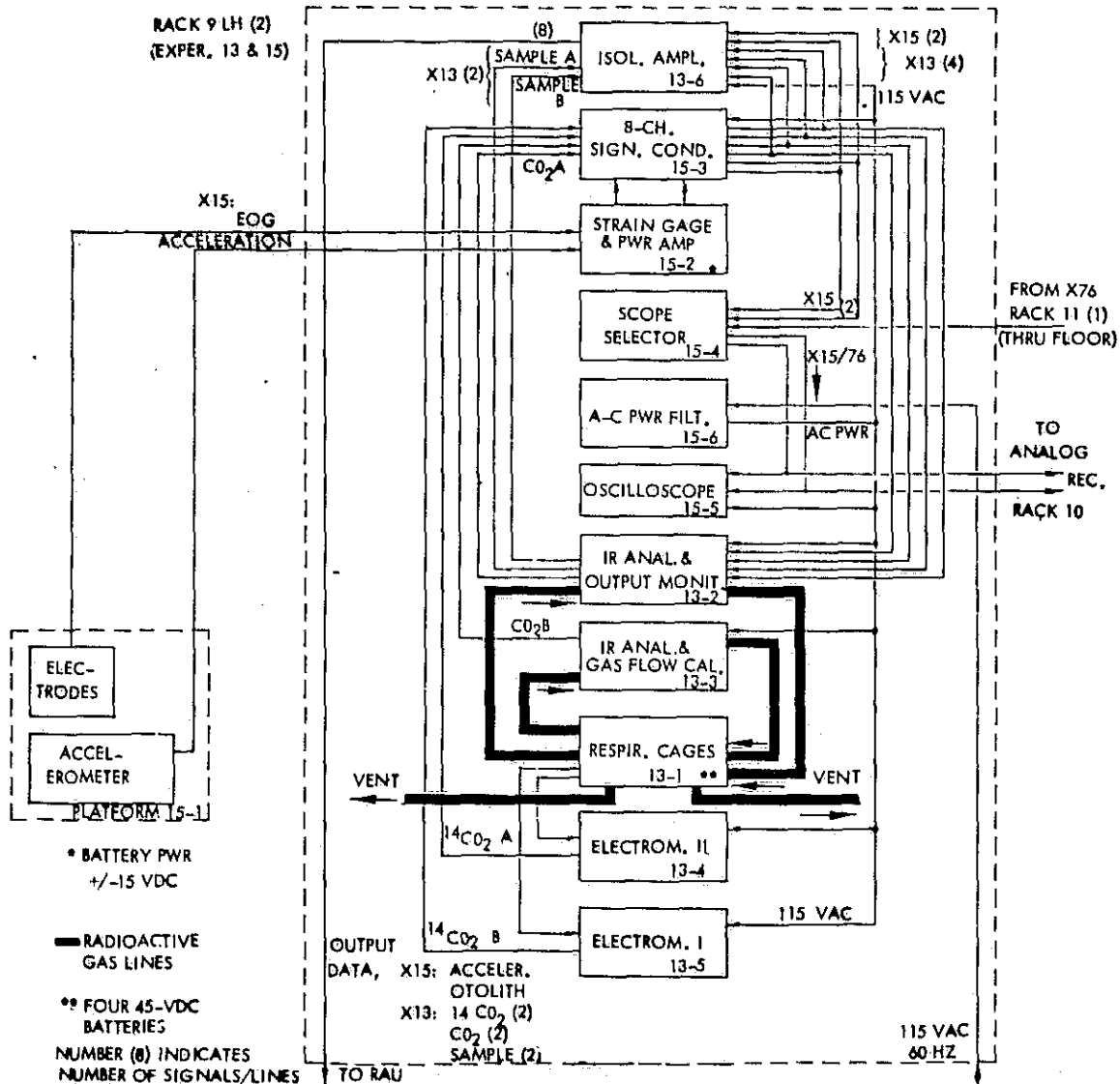


Figure 4-11. Experiment Equipment Interface Schematic for Rack 9 and Associated Center Aisle (Floor Segment 3)



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RACK 10 (1B & 19) (EXPER. 59/60)

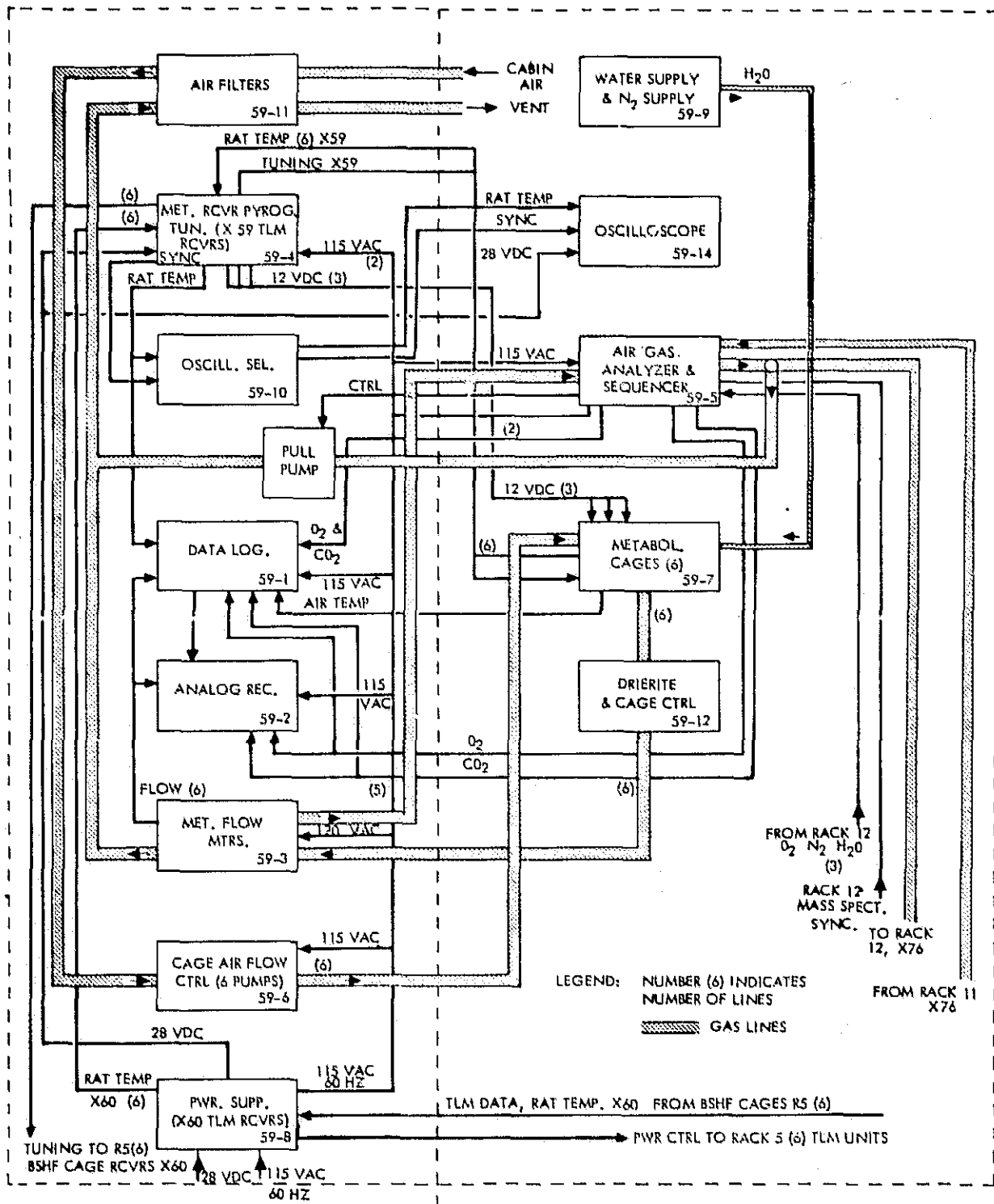


Figure 4-12. Experiment Equipment Interface Schematic for Rack 10

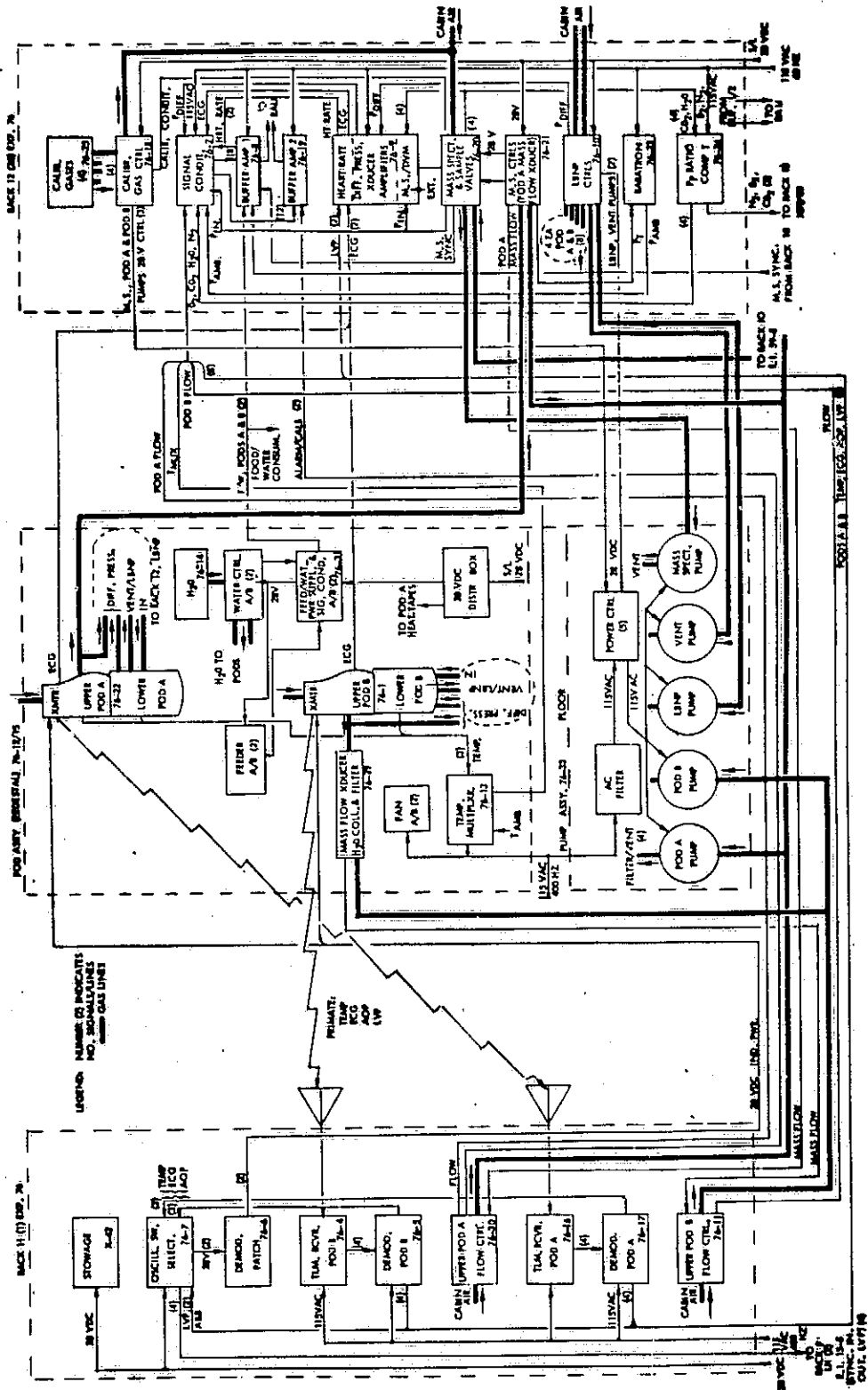


Figure 4-13. Experiment Equipment Interface Schematic for Racks 11, 12 & Floor Segment 4



Table 4-3. Data Interfaces

Inter-connect	Experiment	Output	To
Rack 3 End Items	X-49	Left Ventricle (Video) Doppler Audio Precordial Acceleration EKG Heart Rate Systolic Pressure Diastolic Pressure EKG Arterial Flow	Bus, Rack 2 Rack 4 Strip Chart Recorder and RAU Rack 4 BPMS Rack 10, Analog Recorder
	X-66	Audio Signal Nerve Volts EKG IRIG B (Platform) Angular Speed (") Angular Position Synch	Rack 10, Analog Recorder and RAU
	49/66 51/66	Tilt Angle-28 VDC CTRL Rotational Speed-CTRL	CACB, Aisle - Rotating Base
	X-66 X-66	Slow Code Nerve Event	RAU
Rotating Base	49/66 51/66	Angular Position Angular Speed	CACB, Aisle - Rack 3
Rack 4 End Items	X-49	EKG Count Systolic Pressure Diastolic Pressure	
	X-58	O ₂ CO ₂ N ₂ Spirometer Displacement	HDRM, Rack 2
	X-75	Spirometer Displacement Temperature Pressure Flow	HDRM, Rack 2 and Rack 9



Table 4-3. Data Interfaces (continued)

Inter-connect	Experiment	Output	To
Rack 4 (Cont'd)	All	Radioisotope Data	Analog Recorder, Rack 10
	X-58	Flow	RAU
Rack 5	X-60	Rat Temperature (6)	Rack 10 TLM Receiver
Rack 9 End Items	15/76	Scope Selection Synch	Rack 10, Analog Recorder
	X-13	14 CO ₂ (2) CO ₂ (2) Sample (2)	RAU
	X-15	Acceleration Otolith (EOG)	
Rack 10	X-60	Tuning Control (6) TLM Power Control (6)	TLM Cages, Rack 5
Rack 11 End Items	X-76	Synch Out Synch In LVP A LVP B	Oscill. Select., Rack 9
		28 VDC Induct. Power	Xmtr - Pod Assy.
		Pod A Flow Pod B Flow Alarm/Cal. (2) Pods A/B Temperature (2) " " ECG (2) " " AOP (2) " " LVP (2)	End Items, Rack 12 and RAU
Pod Assy	X-76	Pod B Mass Flow Temperature, Multiplexed Pods A/B ECG (2) " " Feed (2) " " Water (2)	Rack 11 Rack 12 & RAU End Items, Rack 12 End Items, Rack 12 and RAU
Rack 12 End Items	X-76	Pods A/B Pumps 28 VDC CTRL LBNP Pump 28 VDC CTRL Vent " " " " Mass Spectrometer 28 VDC CTRL	Pump Assy
		N ₂ O ₂ CO ₂	Rack 10



Table 4-3. Data Interfaces (continued)

Inter-connect	Experiment	Output	To
Rack 12 (Cont'd)	X-76 (cont'd)	Pod A Mass Flow	Rack 11
		Pod A/B Flow Temperature (Multiplexed) Pod A/B Temperature " " ECG " " AOP " " LVP O ₂ CO ₂ H ₂ O N ₂ Pressure, Ambient Pressure, Inlet Pressure, Differential ECG (Calib.) Heart Rate Food/Water Consumption Pod A " " " Pod B Alarm/Cals (2) Mass Spectrometer Synch (2)	RAU

Cabling and Plumbing Requirements

Specific inter- and intra-experiment end item interconnections were established in order to provide the following information: (1) number of fluid lines and cables and their approximate length to determine work load; (2) capability of making connections at Level IV to determine both the need for interim connections/disconnections, and deferments to Level III; and (3) the experiment-to-Spacelab (RAU, EPSP, etc.) interconnections to determine requirements for availability of such Spacelab hardware at Level IV.

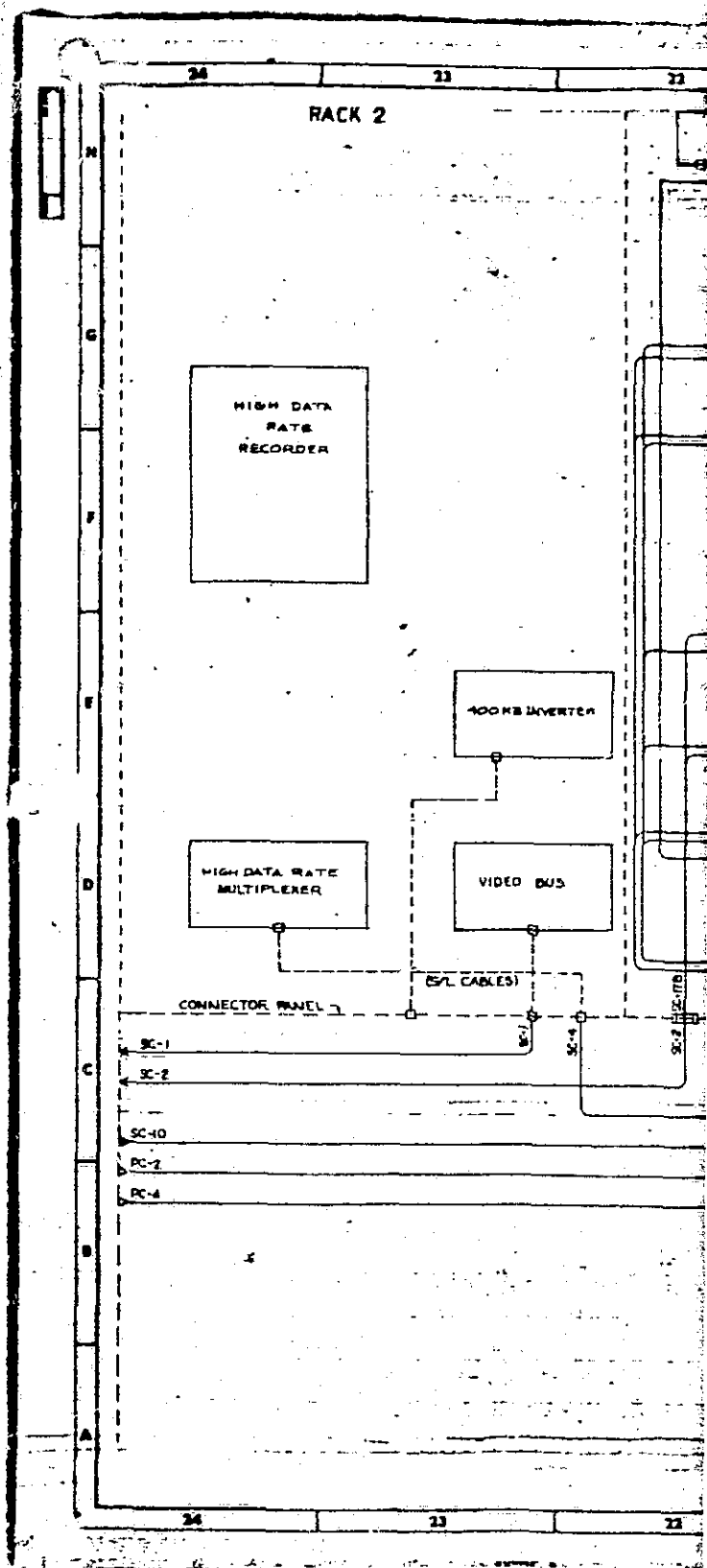
Using the functional schematics, previously described, a total payload cable harness diagram was prepared (Figure 4-14). The branching of intra-rack power and signal cables, and the inter-rack/floor harnesses is indicated in the diagram. A supporting list of cables, Table 4-4, also identifies the length of each cable harness, which was used in the development of installation time estimates.

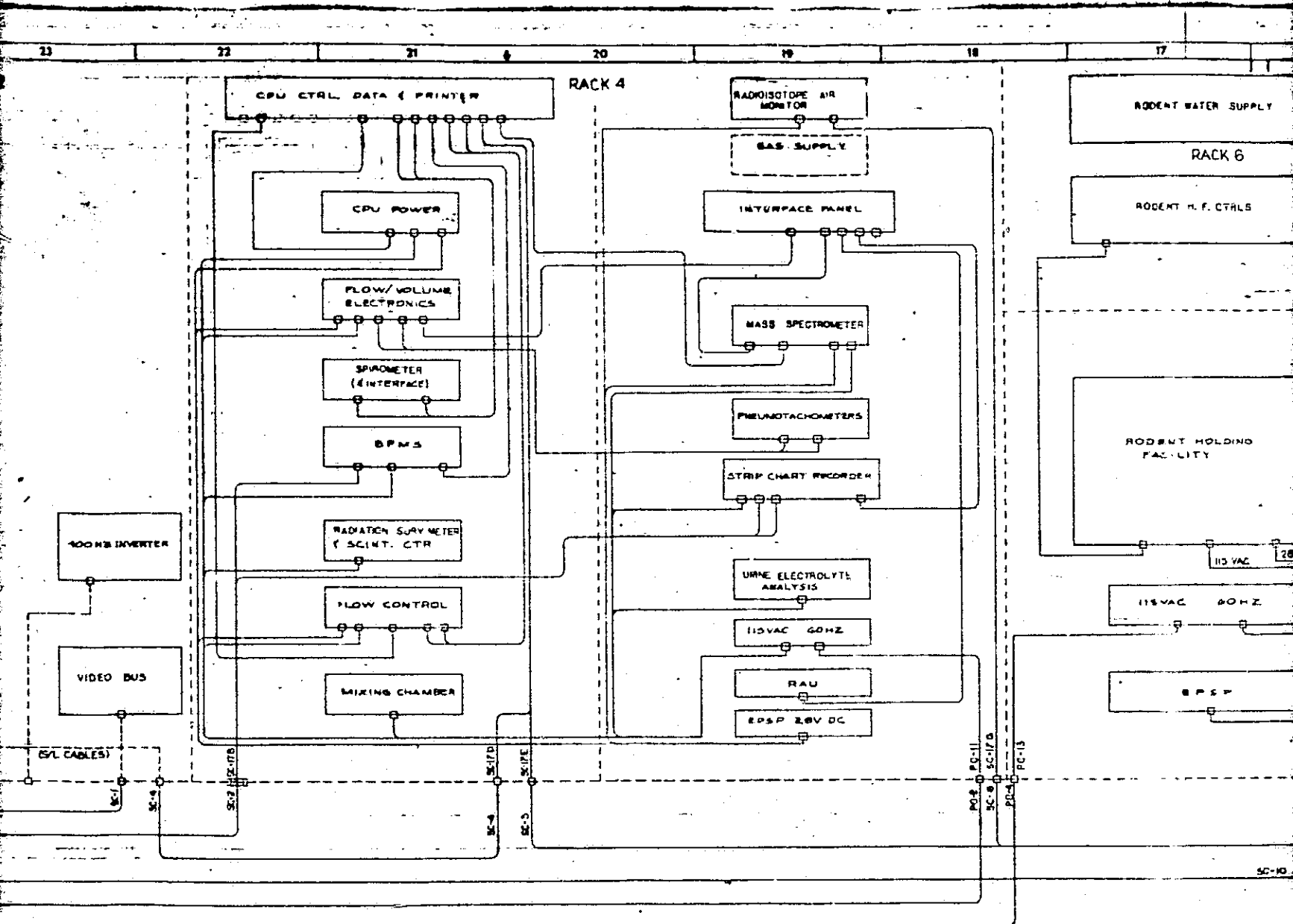


For the Life Sciences payload, fluid line interconnections are a significant integration task. In order to establish realistic estimates for this task, a plan view layout was prepared. The layout, Figure 4-15, indicates the routing (schematically) and number of fluid lines required as well as the inter-rack cables. These data then allowed determination of workload, serial time, and level at which integration could occur. Installation criteria and time estimates for the integration of the Life Sciences payload are presented in Volume II of this report.

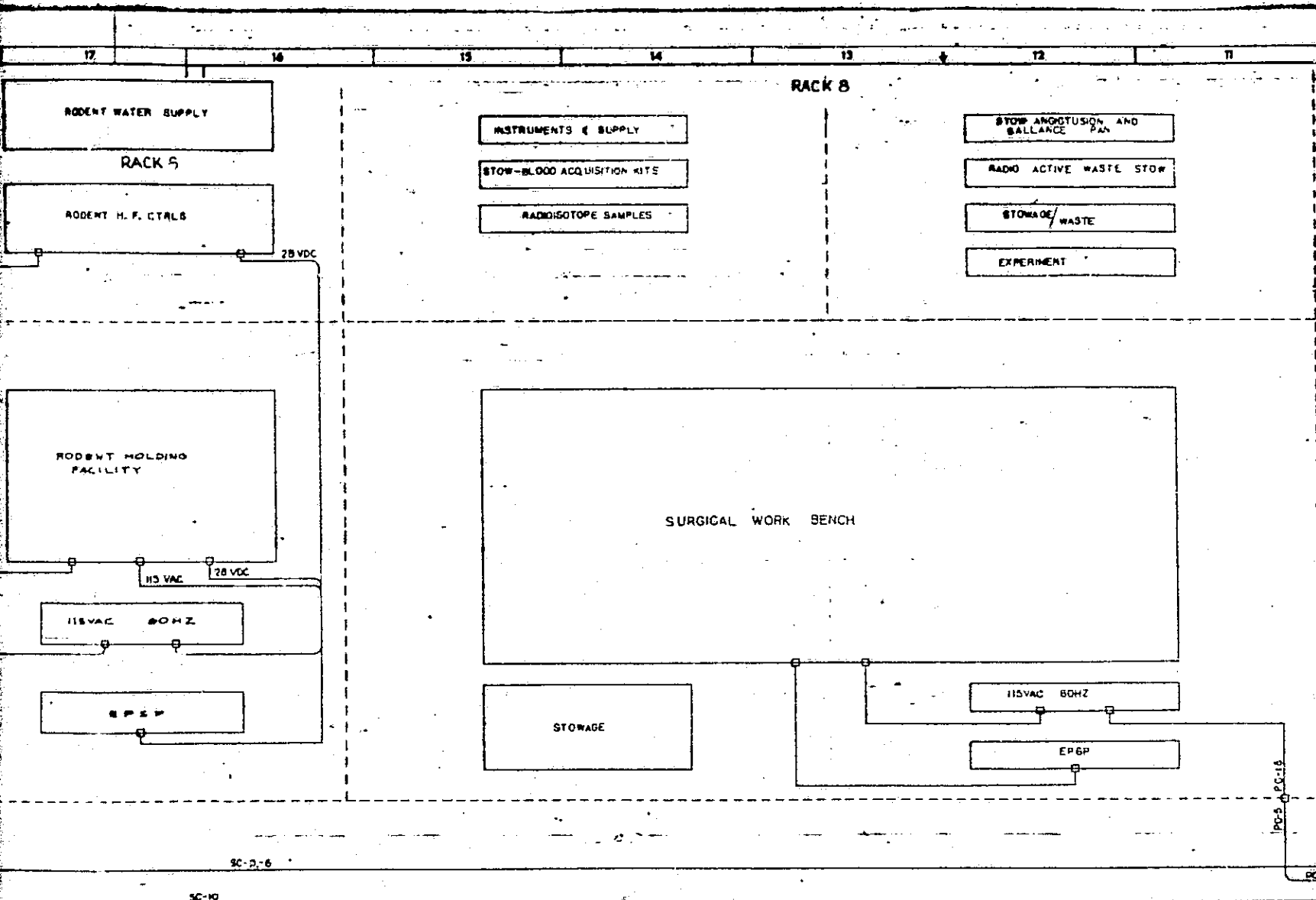
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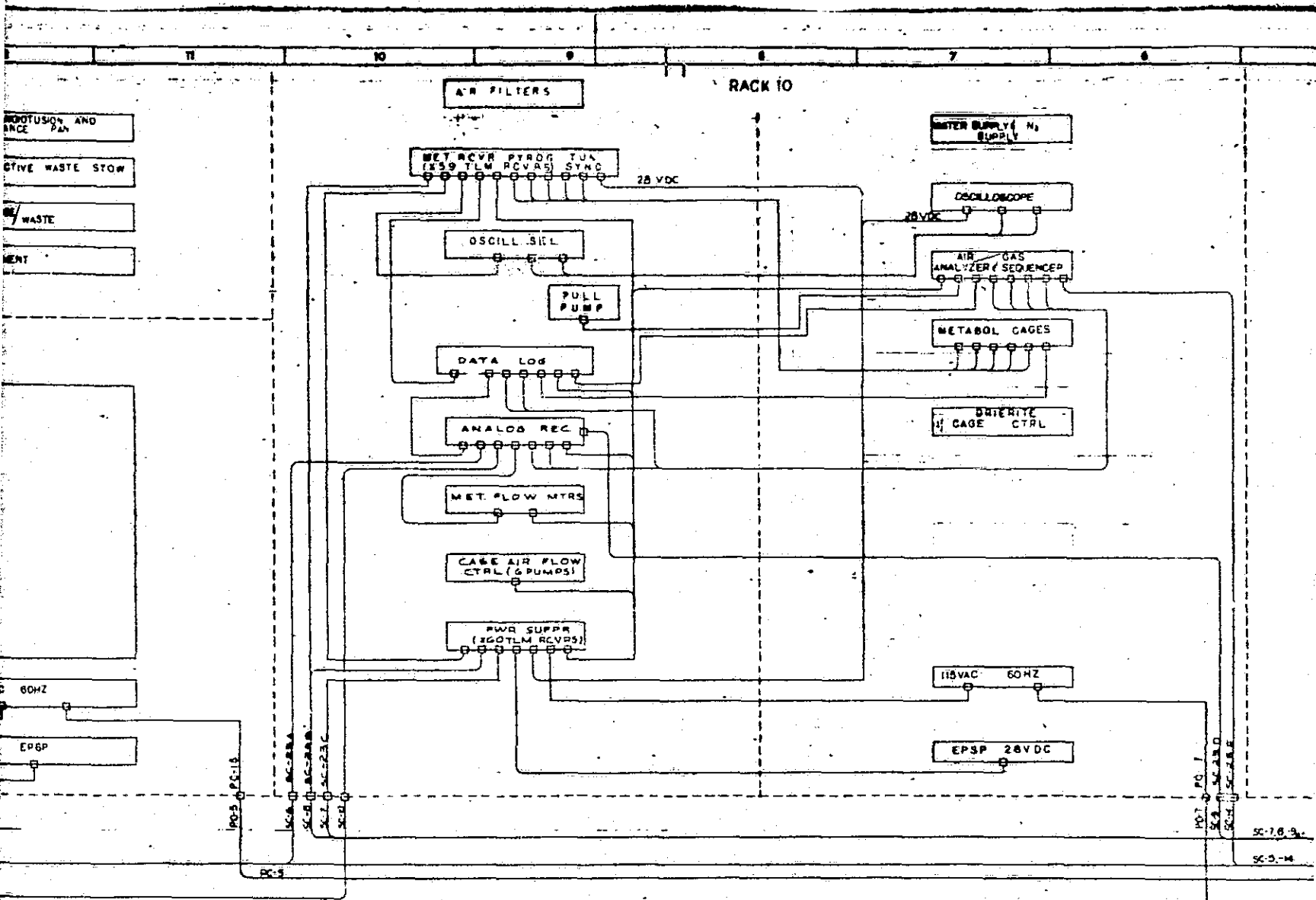




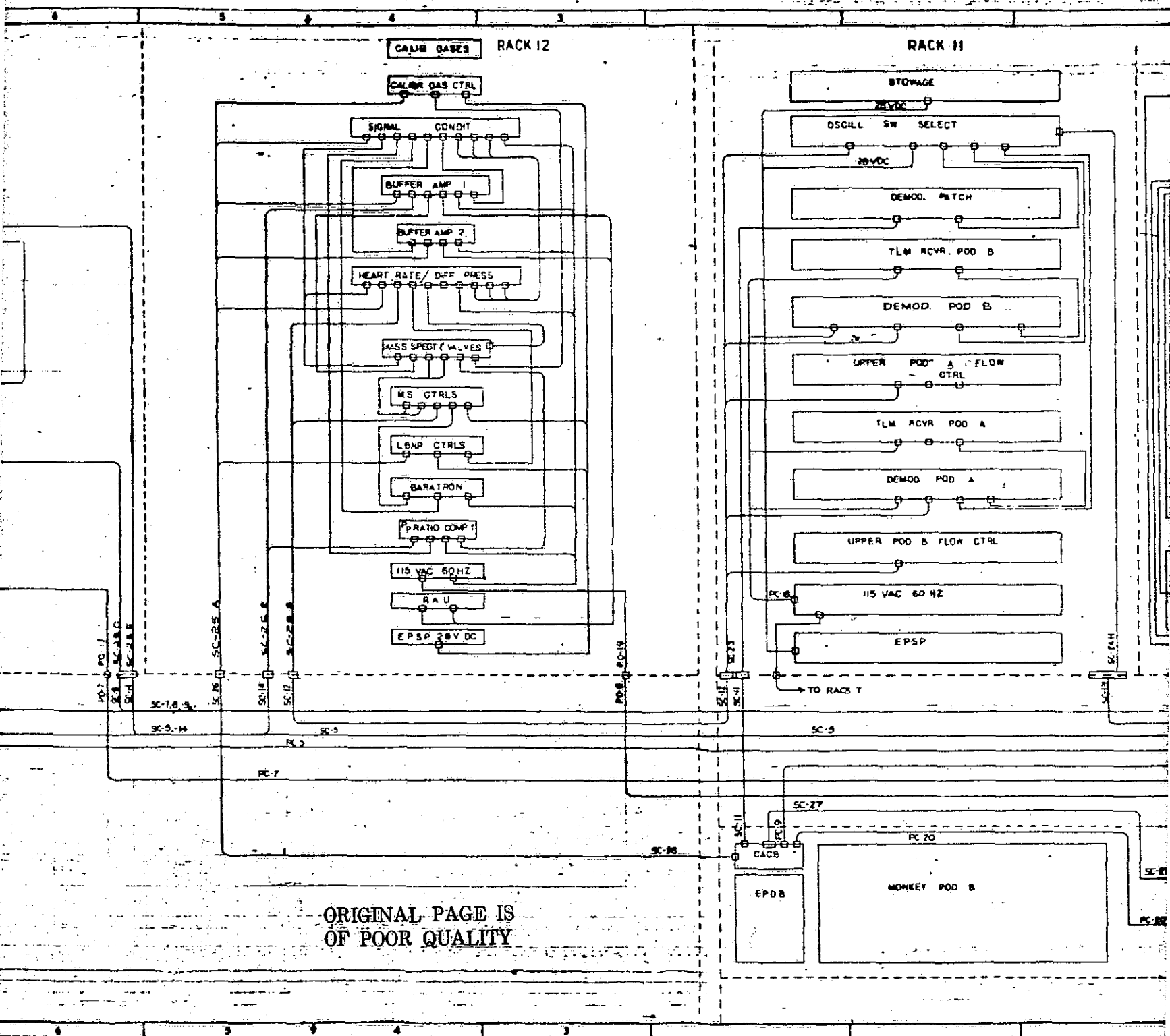
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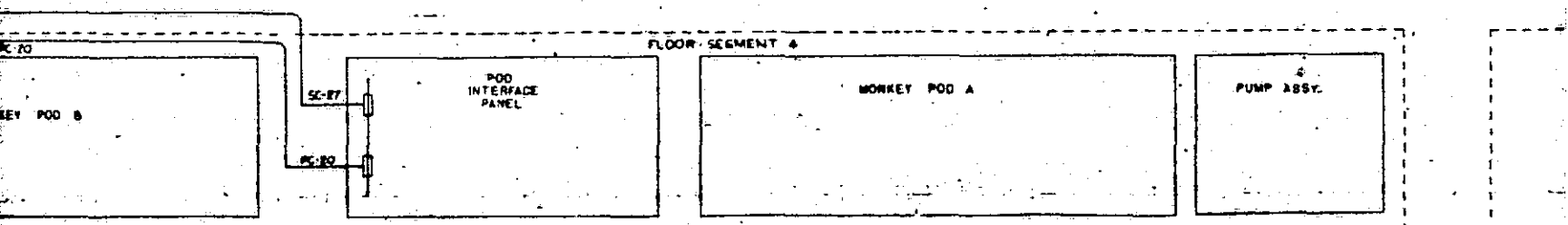
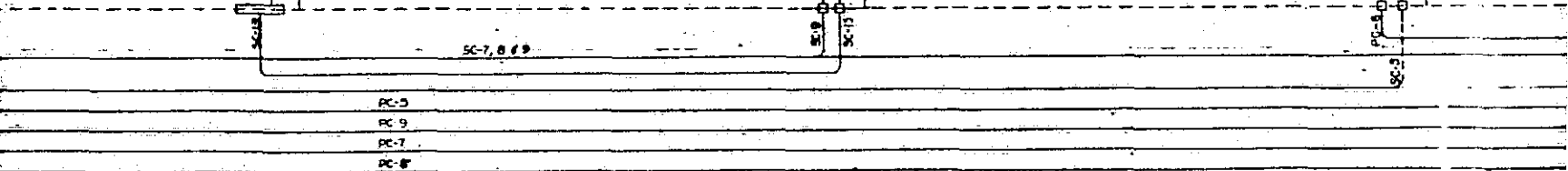
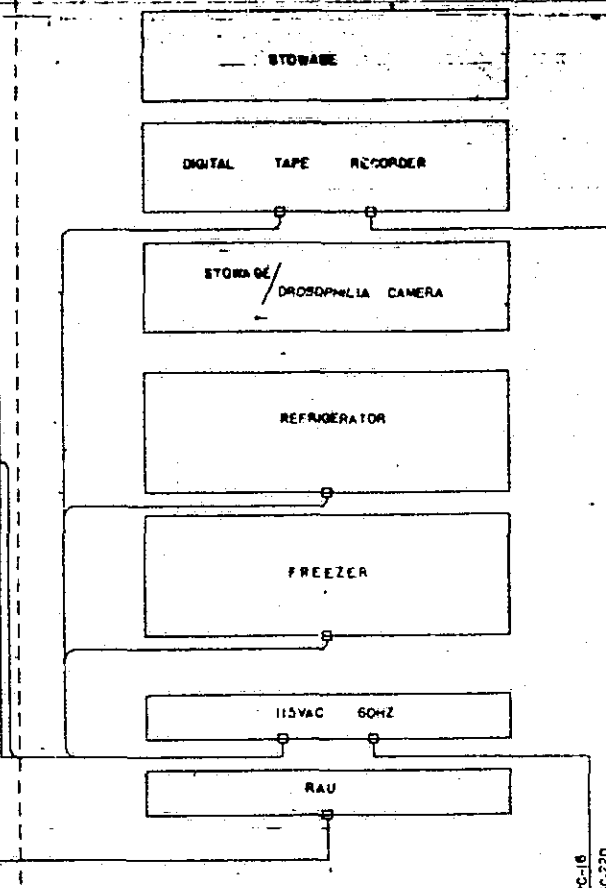
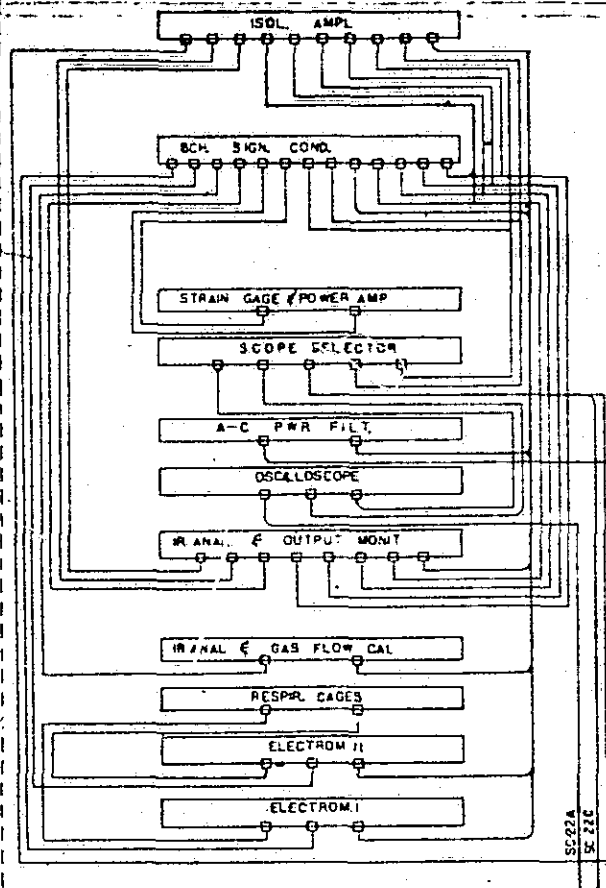
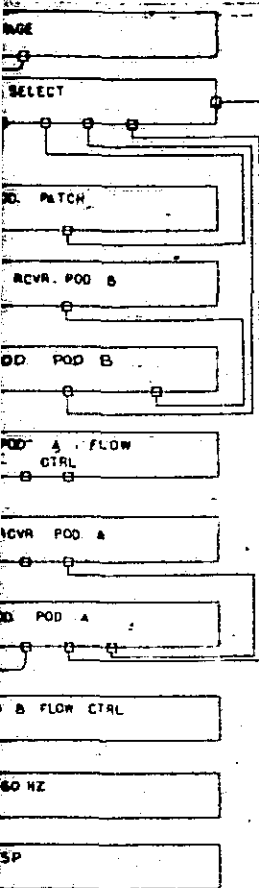
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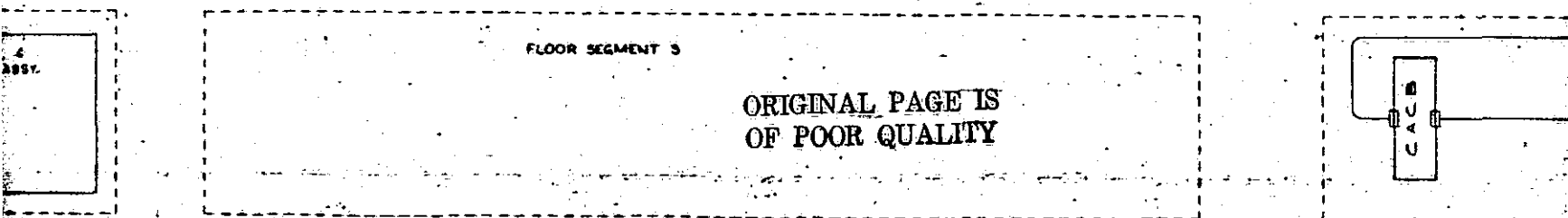
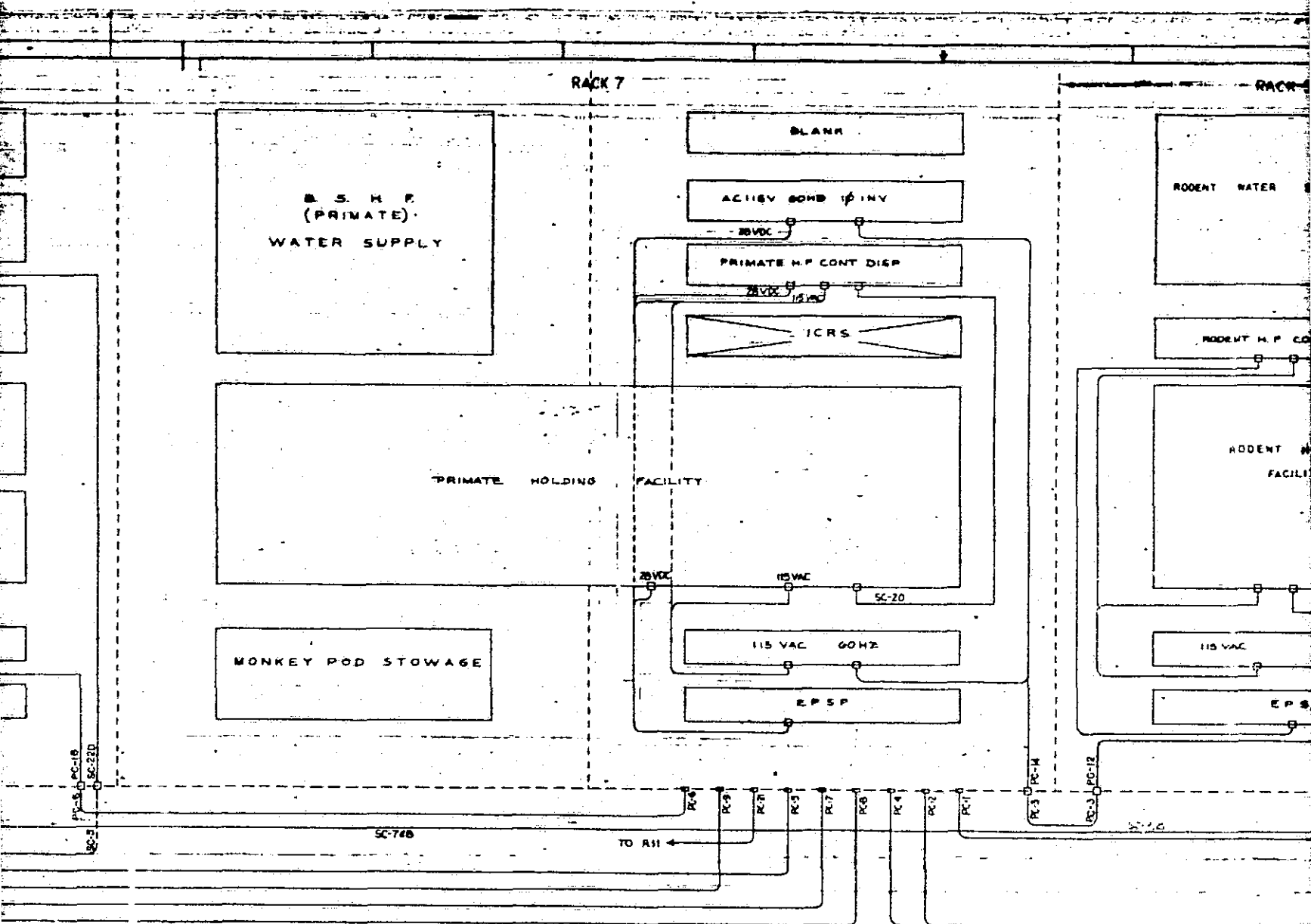
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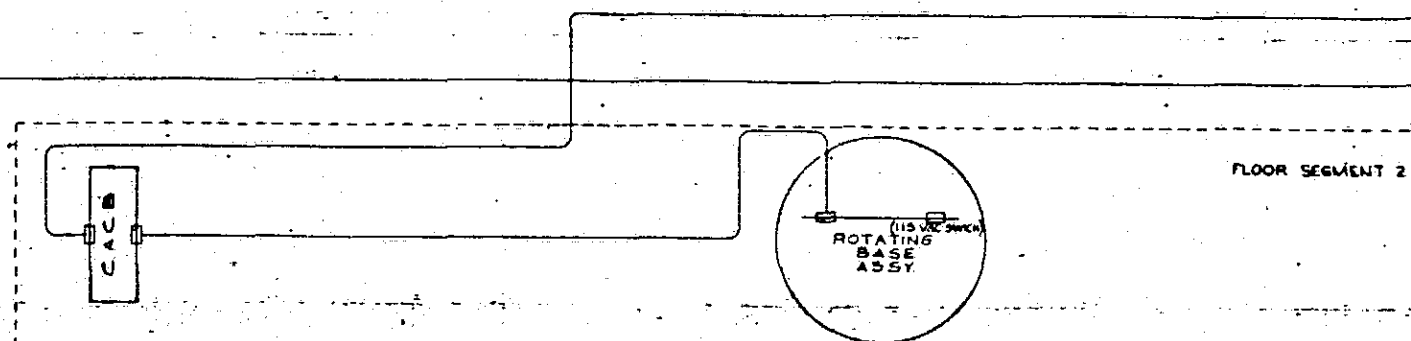
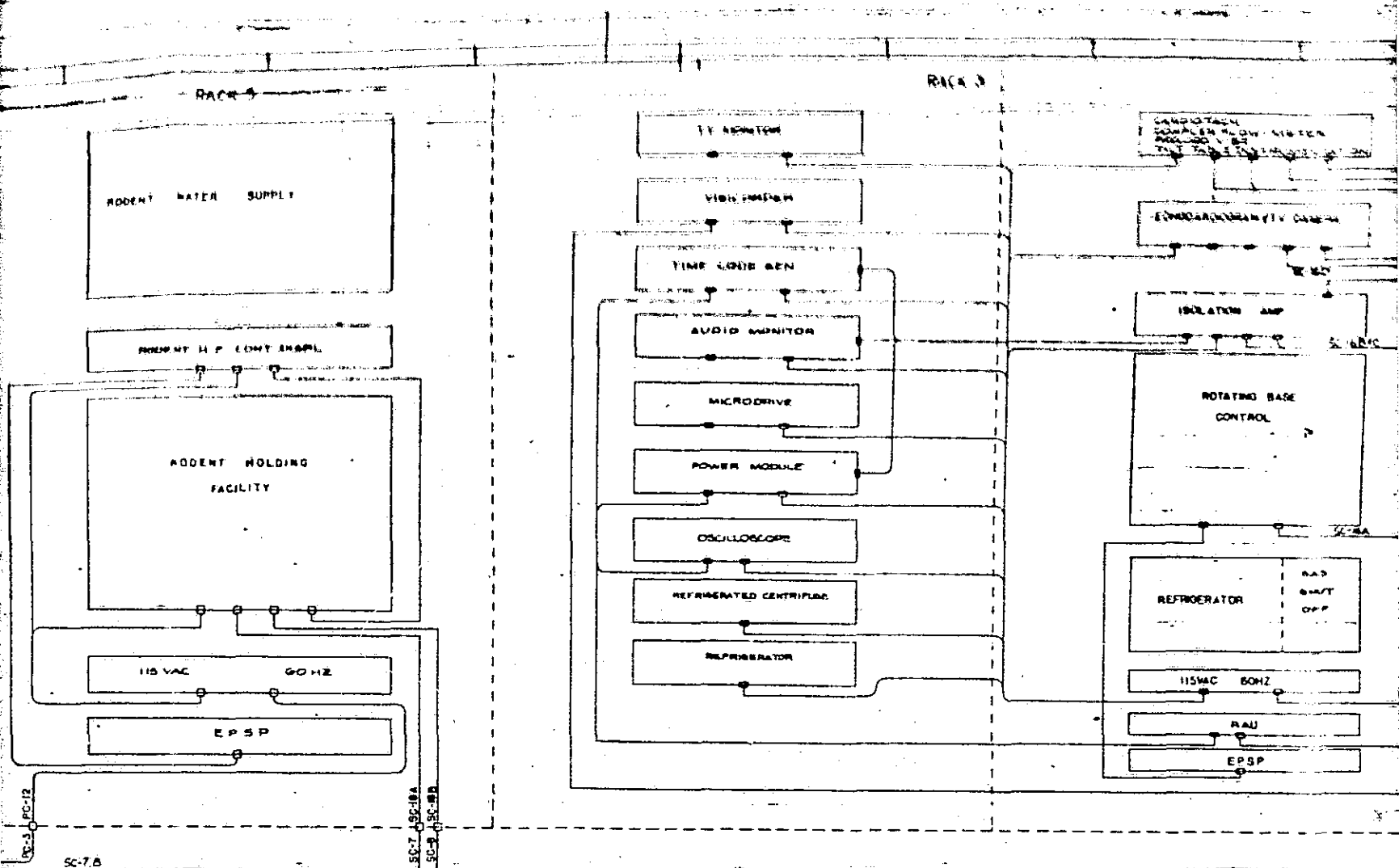
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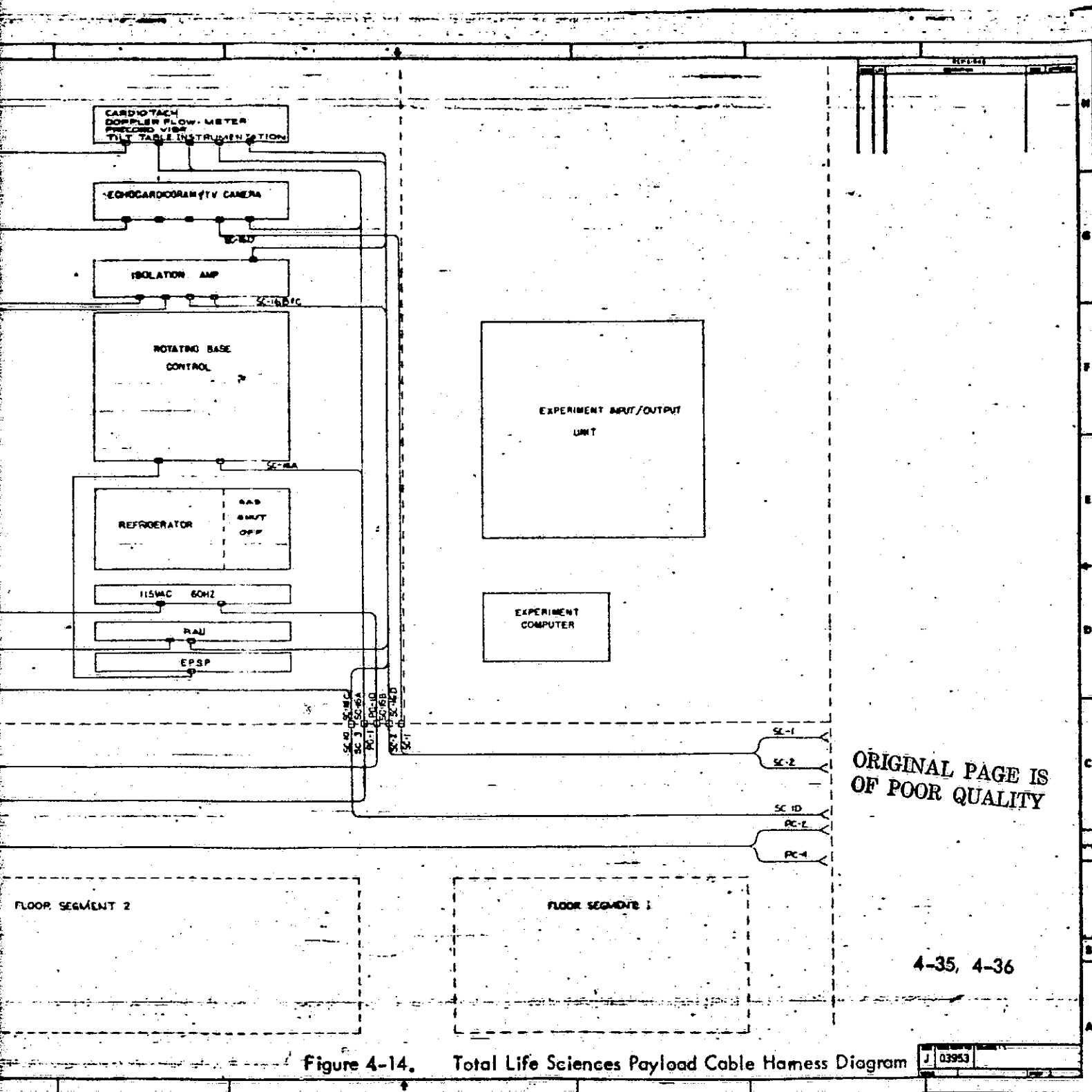


Figure 4-14. Total Life Sciences Payload Cable Harness Diagram

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Table 4-4. Life Sciences Laboratory Cable List

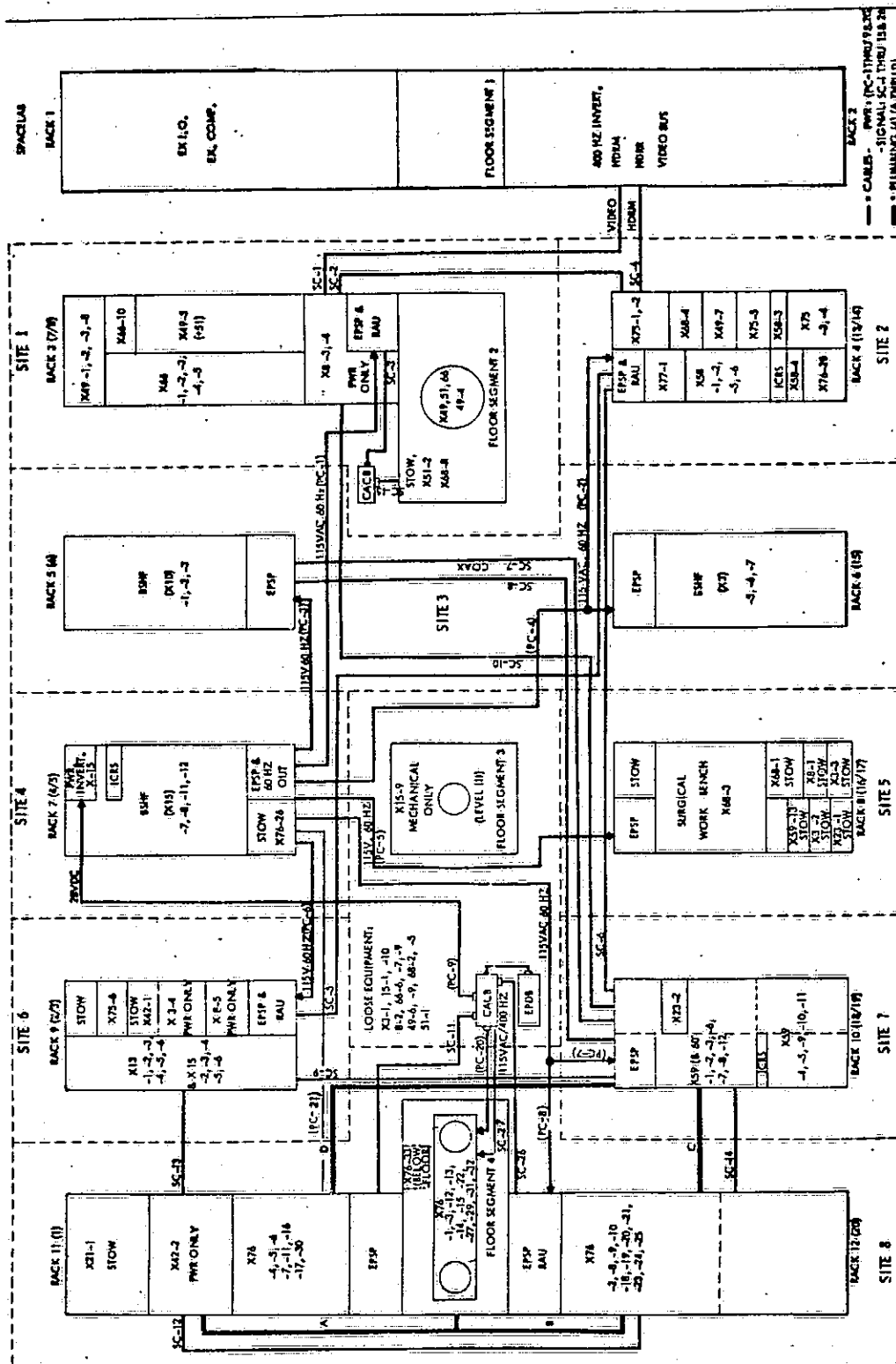
Rack No./Location	Cable No.	From	To	Length
Rack 7	PC-1	Conn Pnl	Rack 3 Conn Pnl	4'
"	PC-2	Conn Pnl	Rack 4 Conn Pnl	12'
"	PC-3	Conn Pnl	Rack 5 Conn Pnl	3'
"	PC-4	Conn Pnl	Rack 6 Conn Pnl	10'
"	PC-5	Conn Pnl	Rack 8 Conn Pnl	11'
"	PC-6	Conn Pnl	Rack 9 Conn Pnl	4'
"	PC-7	Conn Pnl	Rack 10 Conn Pnl	10'
"	PC-8	Conn Pnl	Rack 12 Conn Pnl	12'
"	PC-21	Conn Pnl	Rack 11 " "	12'
Center Aisle	PC-9	CACB F.S. #4	Rack 7 Conn Pnl	9'
Rack 3	SC-1 (COAX)	Conn Pnl	Rack 2 Conn Pnl	10'
"	SC-2	Conn Pnl	Rack 4 Conn Pnl	11'
"	SC-3	Conn Pnl	CACB (F.S.-2)	4'
Rack 4	SC-4	Conn Pnl	Rack 2 Conn Pnl	3'
"	SC-5	Conn Pnl	Rack 9 Conn Pnl	15'
"	SC-6	Conn Pnl	Rack 10 Conn Pnl	8'
Rack 5	SC-7 (COAX)	Conn Pnl	Rack 10 Conn Pnl	11'
"	SC-8	Conn Pnl	Rack 10 Conn Pnl	11'
Rack 9	SC-9	Conn Pnl	Rack 10 Conn Pnl	11'
Rack 10	SC-10	Conn Pnl	Rack 3 Conn Pnl	15'
Rack 11	SC-11	Conn Pnl	FS 4 CACB	6'
"	SC-12	Conn Pnl	Rack 12 Conn Pnl	11'
"	SC-13	Conn Pnl	Rack 9 Conn Pnl	4'
Rack 12	SC-14	Conn Pnl	Rack 10 Conn Pnl	4'
Center Aisle	SC-15	CACB	FS-2	4'



Table 4-4. Life Sciences Laboratory Cable List (continued)

Rack No./Location	Cable No.	From	To	Length
Rack 3	PC-10	Conn Pnl (PC-1)	Rack 3 End Items	6
	SC-16	Conn Pnl (SC-1, -2, -3, 10)	Rack 3 End Items	6
Rack 4	PC-11	Conn Pnl (PC-2)	Rack 4 End Items	6
	SC-17	Conn Pnl (SC-2, 4, 5, 6)	Rack 4 End Items	6
Rack 5	PC-12	Conn Pnl (PC-3)	Rack 5 End Items	6
	SC-18	Conn Pnl (SC-7, -8)	Rack 5 End Items	6
Rack 6	PC-13	Conn Pnl (PC-4)	Rack 6 End Items	6
	SC-19	Conn Pnl	Rack 6 End Items	6
Rack 7	PC-14	Conn Pnl	Rack 7 End Items	6
	SC-20	Conn Pnl	Rack 7 End Items	6
Rack 8	PC-15	Conn Pnl (PC-5)	Rack 8 End Items	6
	SC-21	Conn Pnl	Rack 8 End Items	6
Rack 9	PC-16	Conn Pnl (PC-6)	Rack 9 End Items	6
	SC-22	Conn Pnl (SC-5, 9, 13)	Rack 9 End Items	6
Rack 10	PC-17	Conn Pnl (PC-7)	Rack 10 End Items	6
	SC-23	Conn Pnl (SC-6, 7, 8, 9, 10, 14)	Rack 10 End Items	6
Rack 11	PC-18	Conn Pnl	Rack 11 End Items	6
	SC-24	Conn Pnl (SC-11, 12, 13)	Rack 11 End Items	6
Rack 12	PC-19	Conn Pnl (PC-8)	Rack 12 End Items	6
	SC-25	Conn Pnl (SC-12, 14, 26)	Rack 12 End Items	6
Center Aisle	PC-20	F.S. #4 CACB	Monkey Pod Assembly	4
	SC-26 SC-27	F.S. #4 CACB " "	Rack 12 Monkey Pod Assembly	6

Note: FS = Floor Segment
PC = POWER CABLE
SC = SIGNAL CABLE





5.0 ADVANCED TECHNOLOGY LABORATORY PAYLOAD

INTRODUCTION

The payload used in this study as representative of the multi-disciplined and lab-plus-pallet configuration of the Spacelab traffic model was an Advanced Technology Laboratory (ATL) experiment complement, ATL. This particular payload, ATL-A, was conceptually designed in the ATL Experiment Systems Definition Study, NAS1-14116. Experiments are located on a two-pallet train, in the short module, on a cradle that spans the Orbiter-Spacelab interconnecting crew access tunnel, and in the Orbiter AFD. A list of the ATL experiment complement is provided in Table 5-1. Pallet and cradle-mounted experiments are shown in Figure 5-1. Experiments in the short module are indicated in Figure 5-2; AFD experiments are indicated in Figure 5-3.

Table 5-1. ATL Payload Experiments

Experiment Number	Description
SF-1	Laser Gyro Navigation
SF-2	Short Manipulator (Teleoperator)
ST-1	Drop Dynamics Module
ST-2	Environment Contamination Monitor
ST-3	Laser Heterodyne Spectrometer
ST-5	Column Density Monitor
ST-10	Microwave Radiometer
ST-16B	Basic Structural Elements (Erectable)
ST-20	Space Calibration of Solar Cells
ST-21	Two-Phase Heat Transfer
ST-25	Combustion Facility
ST-26	Geophysical Fluid Flow
X-2	Attitude Reference Determination System

EXPERIMENT COMPLEMENT

Detailed descriptions of the objectives, operations, end items, and interconnections of the experiments of the ATL payload are contained in the GPREDP's in Appendix D. A synopsis of the experiments is presented in this section.

Laser Gyro Navigation System (SF-1)

The capability of a self-contained inertial navigation system using laser gyroscopes and accelerometers will be demonstrated with this experiment. The functions to be evaluated with this experiment include: performance of guidance, navigation, and control measurements during the boost phase and

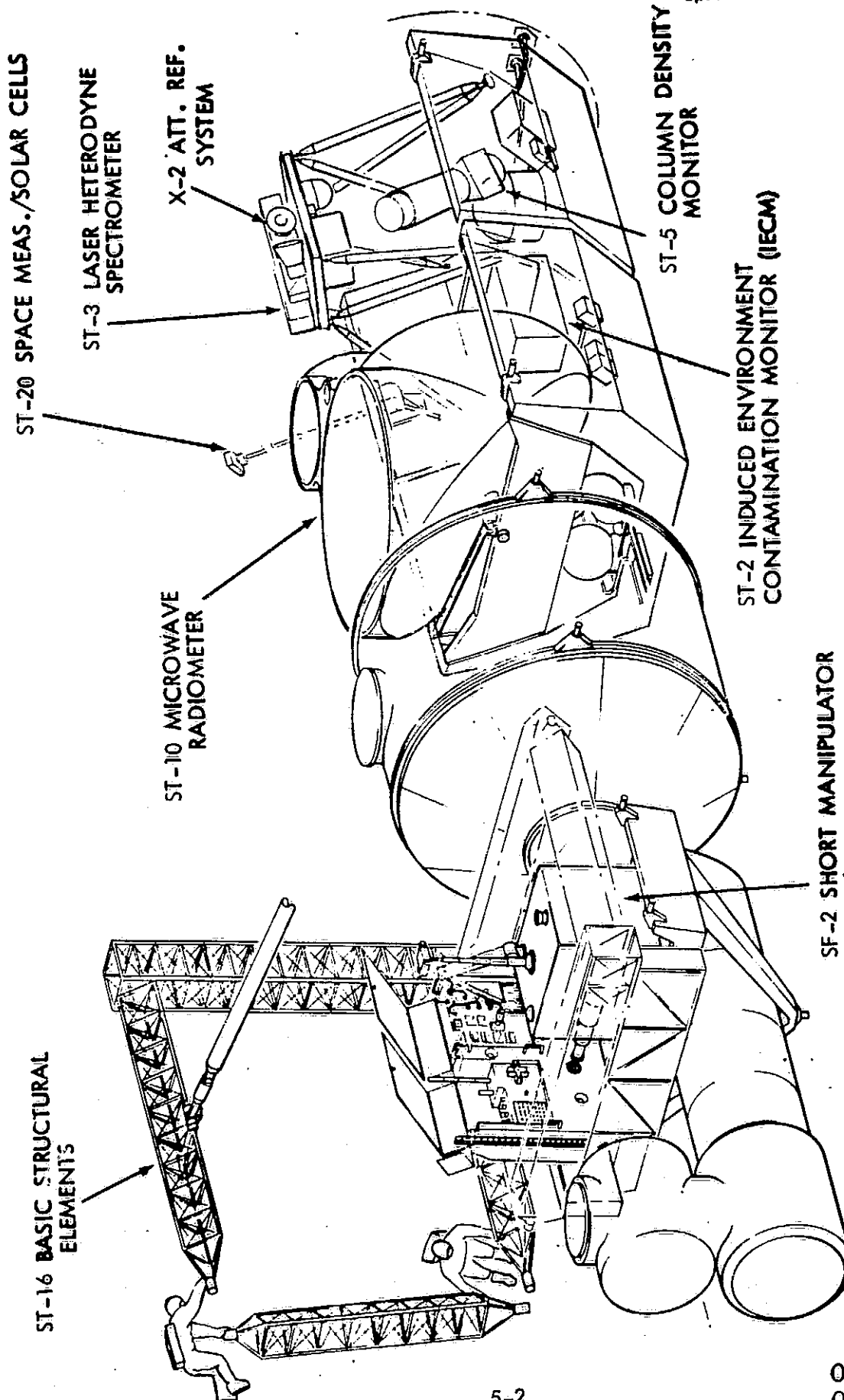
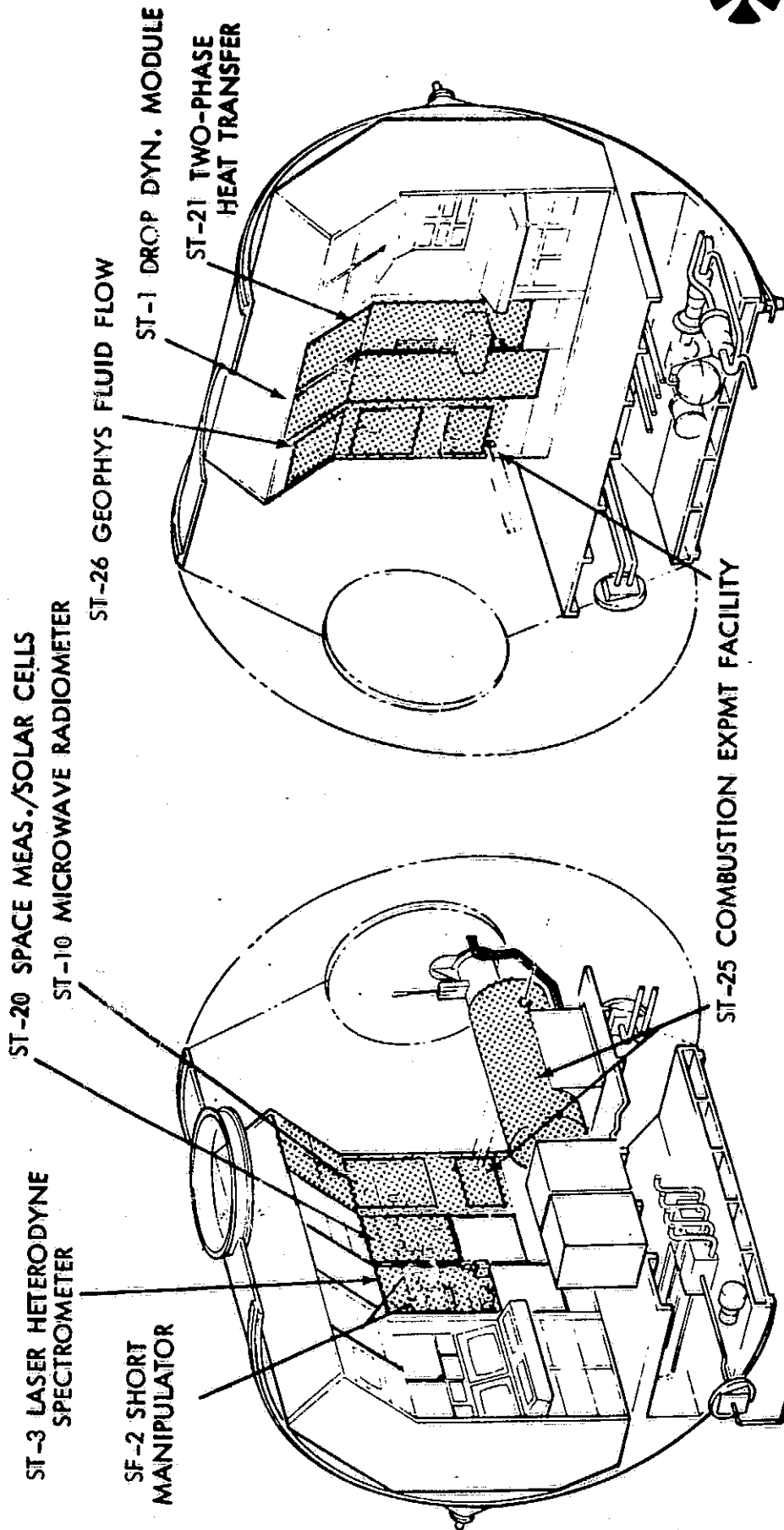


Figure 5-1. Pallet and Cradle-Mounted Experiments



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- CONTROLS FOR ST-2 INDUCED ENVIRONMENT CONTAMINATION MONITOR (IECM), ST-16 BASIC STRUCTURAL ELEMENTS, AND SF-1 LASER GYRO AT PSS

Figure 5-2. Module Arrangement of ATL Experiments



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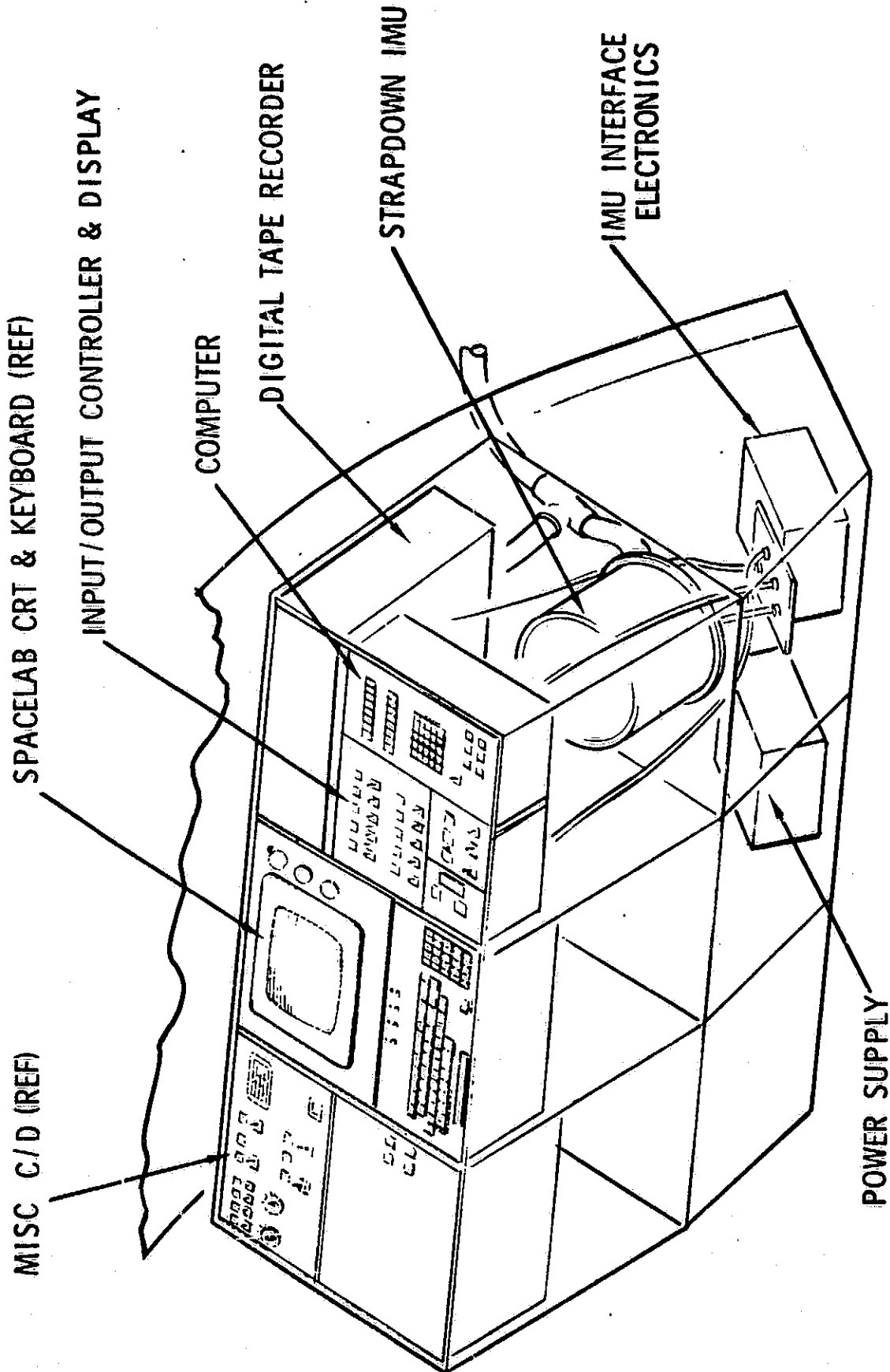


Figure 5-3. ATL Experiment Equipment in Orbiter AFD



orbital mission phases; capability to initialize and align in space; performance of vehicle attitude and angular rates measurements; and performance of redundancy management for reliability.

The plan of investigation is to compare the outputs of the laser gyro navigation system, with the Orbiter system. The laser gyro navigation system provides guidance and navigation outputs that can be compared to the Orbiter inertial measurement unit (IMU) outputs/ground tracking, and also vehicle body rate outputs that can be compared to the Orbiter rate gyros. Both of these precision functions are provided by the redundant strapdown laser gyro navigation system.

The strapdown IMU contains six Sperry Model 8100A ring laser gyros and six Kearfott Model 2401 accelerometers mounted on an integrated IMU structure. The gyros and accelerometers are arranged so the instrument's output axes correspond to vectors normal to six adjacent faces of a dodecahedron. The redundant configuration provides fail operational, fail operational, fail safe sensor management for both the gyros and the accelerometers. The SF-1 experiment includes an SUMC-II computer and an input/output controller. System data will be recorded for post-flight analysis/comparison with recorded Orbiter system data.

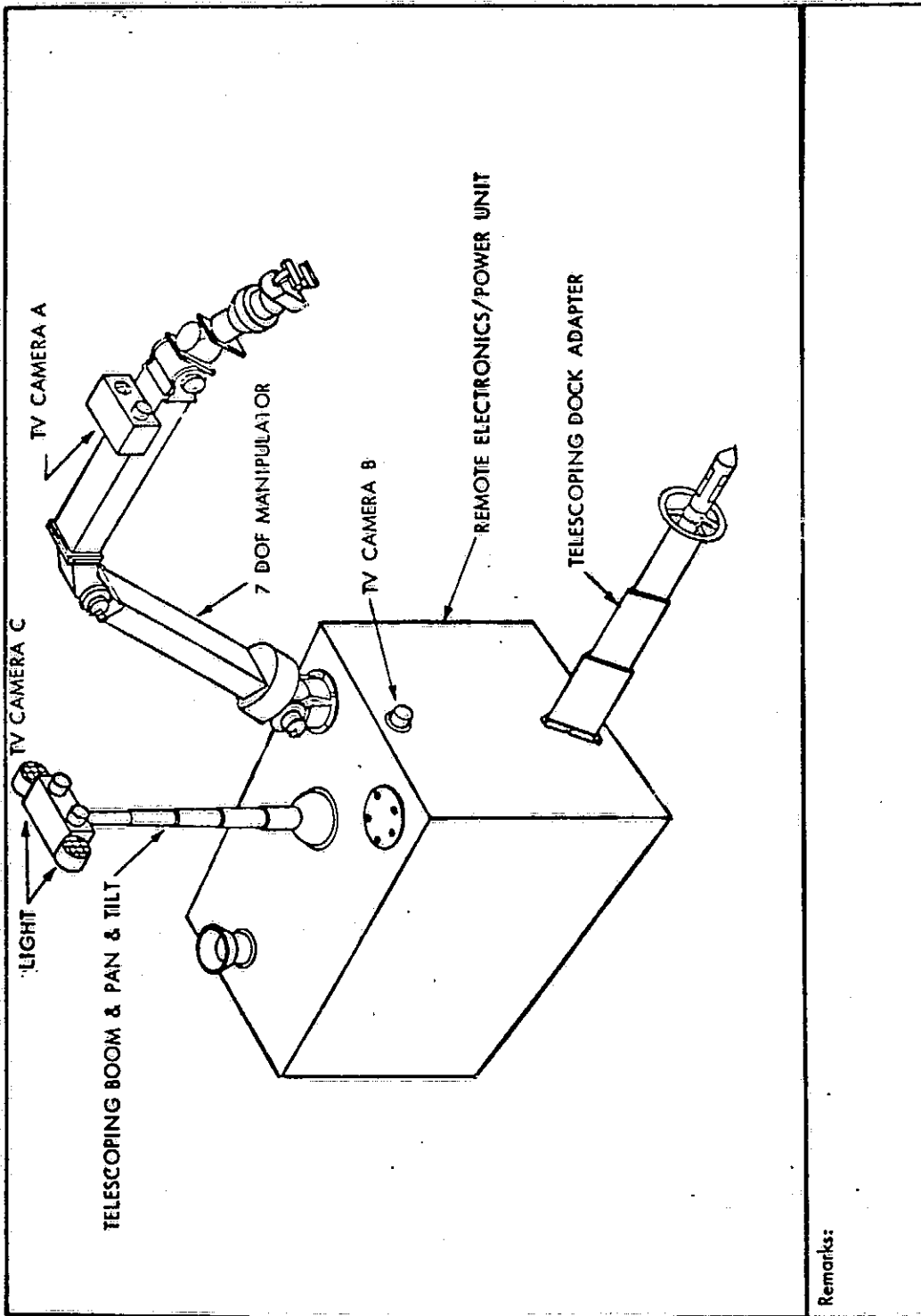
Short Manipulator/Space Teleoperator Demonstration Unit (SF-2)

This experiment will determine an operator's efficiency relative to performing structural assembly tasks in zero-g with time delay comparable to remote assembly of structures in synchronous orbit. A video recording of a flight demonstration will provide an educational aid for development of more sophisticated teleoperator systems for more efficient space operations.

A manipulator system consisting of a 7-degree-of-freedom (DOF) manipulator (Figure 5-4), with appropriate end effectors, sensors, and docking adapter, is used to demonstrate the applicable functions. Control will be performed remotely from the Spacelab module, and will consist of TV monitors/displays, hand controller, etc.

A task board (Figure 5-5) will be furnished to demonstrate the following functions:

- . Unlatch/open compartments
- . Remove/replace modules
- . Disconnect/connect cable connectors
- . Disassembly/assembly
- . Power transfer
- . Close/latch compartments
- . Translate to various docking ports



Remarks:

Figure 5-4. Teleoperator Demonstration Unit



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CONFIGURATION DRAWINGS

End Item(s) 7

Sheet 2 of 2

Page 4 GPR Experiment No.

SF-2

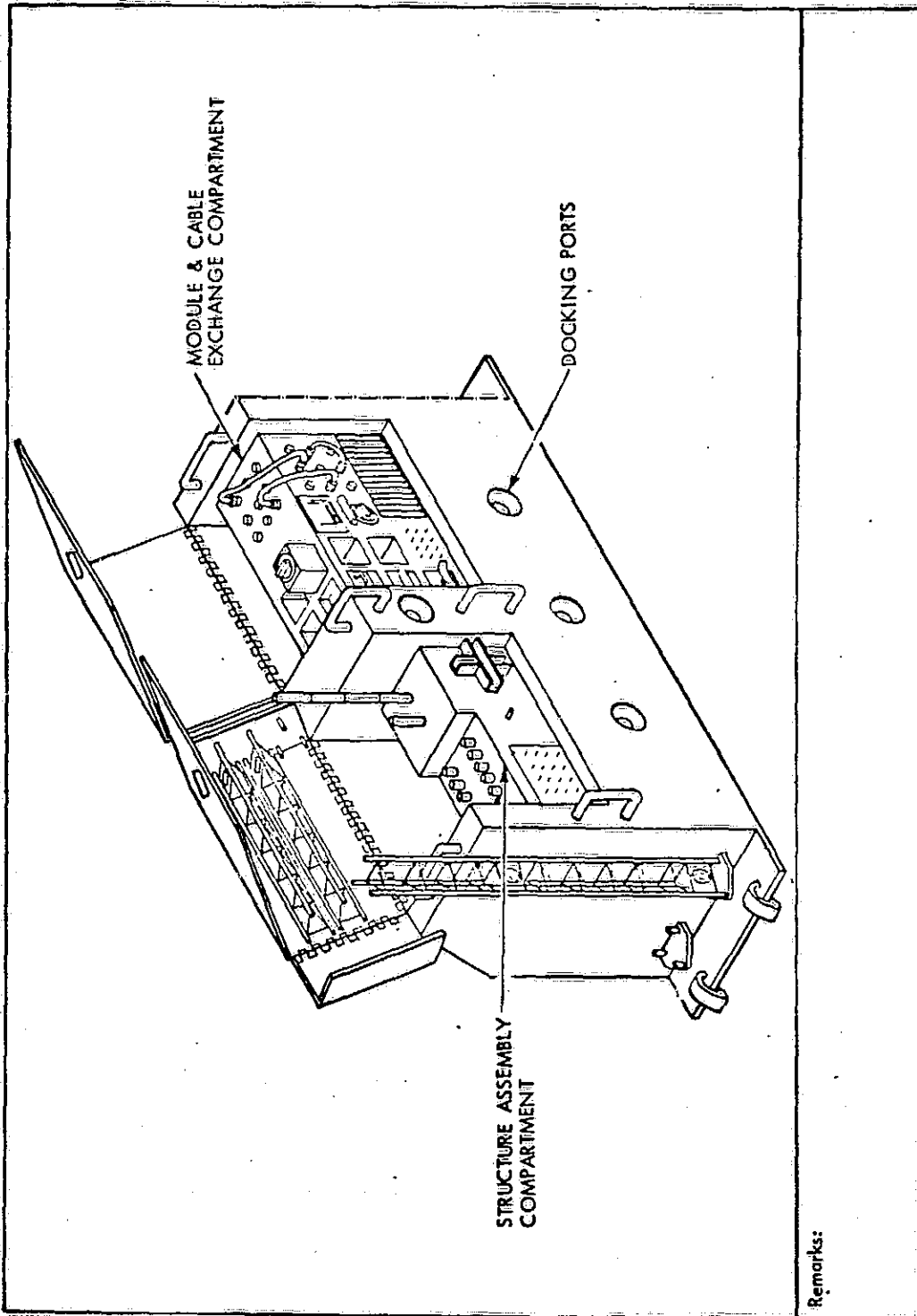


Figure 5-5. Task Board



Drop Dynamics Module (ST-1)

The module consists of a nearly cubic acoustic chamber with acoustic drivers fixed to the center of three mutually perpendicular faces of the chamber. A premeasured amount of liquid is introduced into the center of the chamber by two opposed liquid injectors to null linear momentum. The acoustic drivers, with three-axis freedom, serve to position the droplet in the center. Further, by suitably phasing and/or modulating the speakers, the drop can be caused to rotate and/or oscillate. Sufficient excitation to cause fission can be achieved. Data are recorded photographically, with droplet shape and digitized temperatures, frequency, pressure, phase, acoustic power, pulsing power, acceleration, mode of operation, and time being recorded on the film. Strobe lighting and mirrors are included in the acoustic chamber. A preprogrammed sequencer system, with manual override, controls all phases of the experiment. A system to allow inflight diagnostic and module repair is provided. Crew function is minimal with film change, test initiation, and cleanup following each test being required. Water is the droplet fluid and cabin air the test vapor, so safety and contamination are relatively unimportant considerations. The recovered film is the sole data source and is reduced and analyzed after the flight.

Integrated Environmental Contamination Monitor (ST-2)

The objective of this experiment is to provide physical data on Orbiter payload bay contaminants (dust particles and fluids), and to determine the extent to which such contaminants degrade optical instrumentation and thermal control surfaces because of induced scattering, absorption, and surface blemishing. An additional desire is to measure the amount of contamination deposited, identify the species, and measure the optical properties of the contaminant film.

An ambient air monitor (AAM) system and orbital environment monitor (OEM) system are integrated into one assembly (Figure 5-6). AAM will be operated during payload installation and checkout, launch preparation, ascent, descent, landing, and payload unloading. The OEM will be operated during the orbit phase. The AAM will determine aerosol counts and size distributions while the OEM will map direction fluxes of condensable molecules in the payload bay as a function of time, and measure heats of absorption and evaporation rates. Column densities of various species will also be determined by the OEM as well as the background brightness from unresolved particles. Experiment control is effected at the Payload Specialist Station.

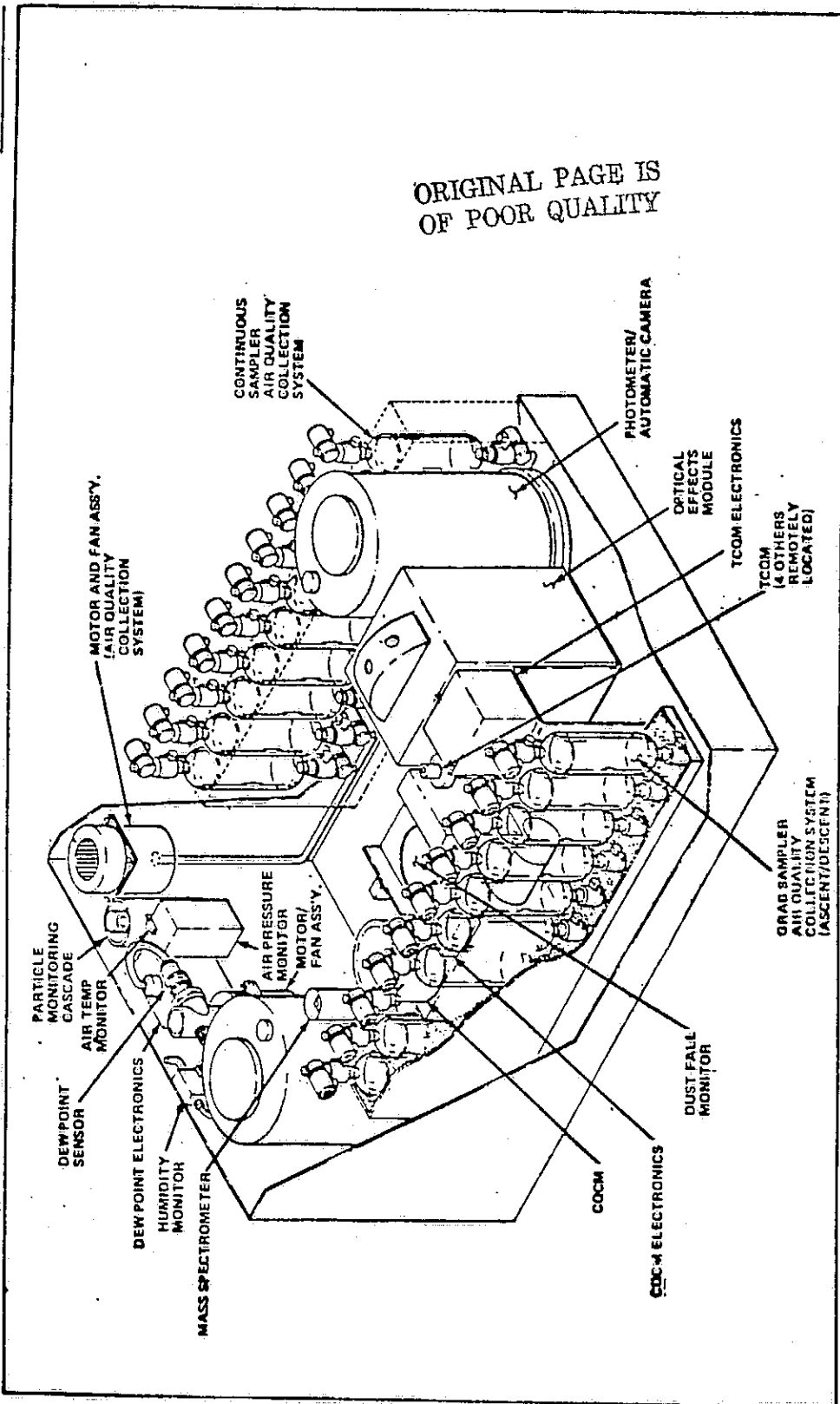
Laser Heterodyne Spectrometer (ST-3)

In optical heterodyne detection the received radiation is mixed on the detector with that of a coherent source, and the intermediate or difference frequency is electrically detected and amplified. Solid-state lasers operating in the infrared serve as coherent sources for the optical mixing process. Since the tunable diode lasers are now available at infrared frequencies it is possible to scan, in wavelength, the received radiation over the absorption bands of the atmospheric molecule of interest. The spectral resolution and heterodyne detection limits of an infrared heterodyne radiometer afford a compact, extremely sensitive means of atmospheric probing.



CONFIGURATIONS

End Item(s) IECM* (1, 2) Sheet 1 of 9 Page 4 GPR Experiment No. SI-2



Remarks:

* Integrated environmental contamination monitor (OEM and AAM).

Figure 5-6. Integrated Environmental Contamination Monitor



This experiment is designed to establish the feasibility of measuring the total vertical column density of molecules observed against the earth background, and the vertical distribution of these molecules by limb measurements against the solar disc background. The vertical column density is determined by scanning the radiometer through the absorption bands and measuring band depth and profiles. The vertical distribution is determined by a series of scans through the atmosphere between instrument and sun as the line of sight descends through the atmosphere during local sunset.

The measuring instrument for the atmospheric probing consists of a telescopic system for collection of radiation; a two-axis scan mirror for maintaining the nadir ground point or the center of the solar disc in the field of view of the telescope during Orbiter motion within the observation time; a battery of tunable diode lasers, each covering a different wavelength range; a refrigeration system for the tunable lasers; an infrared detector with associated cooler, a black body, and a rotatable turret containing gas samples for inflight calibration and checkout of the measurement system; a signal processor and a digital tape recorder for experiment data storage; and control electronics for the various subassemblies.

The telescopic system combines two imaging systems with different fields of view for the nadir and sun viewing modes. Target area tracking is controlled by a preprogrammed scan and track controller referenced to a star tracker to attain the line-of-sight accuracy required. Final target acquisition and verification are accomplished by operator manual control monitored by a TV camera.

Column Density Monitor (ST-5)

The purpose of this investigation is to determine the intensity, spectral character, and temporal variations of the infrared radiation from the Spacelab sky. This radiation arises from the Shuttle/Spacelab contaminants and from diffuse natural sources.

Some of the bands selected for continuous monitoring will permit determination of the column density and effective temperature of contaminant water vapor as functions of time, attitude, altitude, and Shuttle/Spacelab operational modes. Other bands appropriate for determining NO , CO_2 , and OH radiation and zodiacal light continuum will be monitored as well. In addition, these monitors will be able to detect and identify the passage of individual dust particles as small as $4 \mu\text{m}$ at distances up to 70 m, thus testing one of the most elusive and difficult of the astronomical requirements on the Shuttle/Spacelab environment. Results would include a time history of H_2O column density down to about 10^{10} molecules/ cm^2 , a mapping of the zodiacal infrared background and its spectrum, measurement of intensity of radiation from all serious infrared emitting contaminants, and an empirical determination of contaminant particle size and velocity distributions and frequency of sighting.

A sensitive infrared radiometer incorporating detectors, filters, and dispersive elements sufficient for both selective monitoring of expected radiation sources and surveying for unpredicted spectral features through the 1- to 120- μm range will be used. Supercritical helium will be expanded through a Joule-Thompson expander to cool some detectors to 3°K. Other detectors and



optics will also be cooled with helium. Emitting molecules will be identified from the characteristics of their emitted IR radiation.

Microwave Radiometer (ST-10)

The primary objective is the remote measurement of specific oceanographic features of the world's oceans along with certain meteorological characteristics of the atmosphere above the oceans. The pertinent oceanographic parameters to be quantified are salinity, true thermodynamic temperature, roughness (i.e., wave structure), and areal extent of foam coverage of the sea surface. Knowledge of the latter two will permit the surface wind speed to be inferred. The specific meteorological quantities that will be determined are integrated water vapor content, integrated liquid water content in a vertical column, and possibly, rainfall rate. From the measurements the vertical structure of a weather cell may be inferred from sea surface to cloud top.

The equipment consists of L/S-Band, C/X-Band, and K-Band antenna assemblies; associated RF enclosures, main control and auxiliary units; and a control and display panel. The main control units perform analog and digital processing of signals within the radiometer. They also perform correct sequencing and timing operations to ensure repetitive sweeping through all three RF channels. The auxiliary units house appropriate power supplies and provide temperature regulation for the RF enclosures. The RF enclosures amplify weak thermal signals perceived by their corresponding antennas, down convert to immediate frequency with additional IF amplification followed by square law detection, and audio frequency amplification of the modulating signal impressed on the carrier by a circulator switch. Tunnel diode RF amplifiers are used only at L/S- and C/X-Bands. No RF amplification is used at K-Band. The remaining circuitry consists of a voltage-controlled local oscillator, mixer, detector, IF and AF amplifiers, and RF noise injection coupling. Thermal insulation, heat sinking, heaters, and temperature control sensors are provided to establish constant temperature within the enclosure.

The experiment has three pointing modes: (1) nadir; (2) 55 degrees from nadir, normal to the flight path; and (3) at one of the galactic poles for calibration. The mode is altered by a 0.5-deg/sec rotation of the three antennas together, with one cycle of three modes being performed in 24 hours.

Basic Erectable Structural Elements (ST-16B)

Large area erectable space structures have been identified as a critical technology need for a large number of future NASA missions. Hence, technologies need to be developed that will permit the design and construction of large, erectable structures which can be delivered into space, unpacked, assembled, and maintained to the required precision in orientation, shape, stability, and stiffness.

In concert with the mission capability/constraints and the fundamental structural issues associated with the large area space structures, research tests will be conducted in (1) packaging and erection of erectable beam elements, (2) joining of erectable beam elements into simulated complete structure, and (3) the response of the structure to the space environment.



For this purpose, the test hardware involved would represent production-line hardware in terms of manufacturing tolerances, designs, etc., as opposed to more closely controlled laboratory hardware. Figure 5-7 illustrates the assembly sequences for erectable beam element concepts.

It is anticipated that this experiment will require the full-time participation of two crewmen for each of two maximum EVA excursions (six hours of useful EVA each). The major structural assembly will be erected during the first EVA excursion. Vibration/damping and environmental tests then will be performed for several hours. Following these tests, the structural assembly will be jettisoned. The second EVA excursion will be devoted to the erection and joining of several beam segments to examine different joining concepts and beam configurations. The joined beam segments are sized to permit them to be stowed in the cargo bay for return to earth.

Space Calibration of Solar Cells (ST-20)

The objective of this experiment is to continue the solar cell calibration program, taking advantage of the space environment of the Spacelab, and to correlate these data with data obtained in the present program which utilize high-altitude balloon flights. Experiment data will provide the necessary information for the evaluation of existing technology for the new types of high power-to-weight ratio photovoltaic devices being developed for future space solar power applications.

A test plate of candidate solar cells (25 to 50 specimens) calibrated in the space solar irradiance environment is mounted on a solar tracker. The solar tracker, which maintains solar incidence, is located on the end of an extendable boom assembly. Using two 2-axis sun trackers, the point control is capable of maintaining the solar cell test plate within ± 1 degree of the sun. When the sun is more than 80 degrees from the fixed boom direction, solar viewing is impossible; however, solar cell temperatures and (dark current) voltages continue to be measured.

Two-Phase Heat Transfer (ST-21)

The objective is to obtain a better understanding of two-phase fluid mechanics and heat transfer phenomena in a reduced gravity environment. In particular, experiments concerning (1) boiling, (2) bubble dynamics, and (3) two-phase flow will be conducted. Photographs as well as temperature, pressure, and flow data will be taken of the specific phenomena over a range of test parameters using several working fluids. All tests will be performed at $10^{-4}g$ or less, and a water boiling tests will also be made at about $0.010g$.



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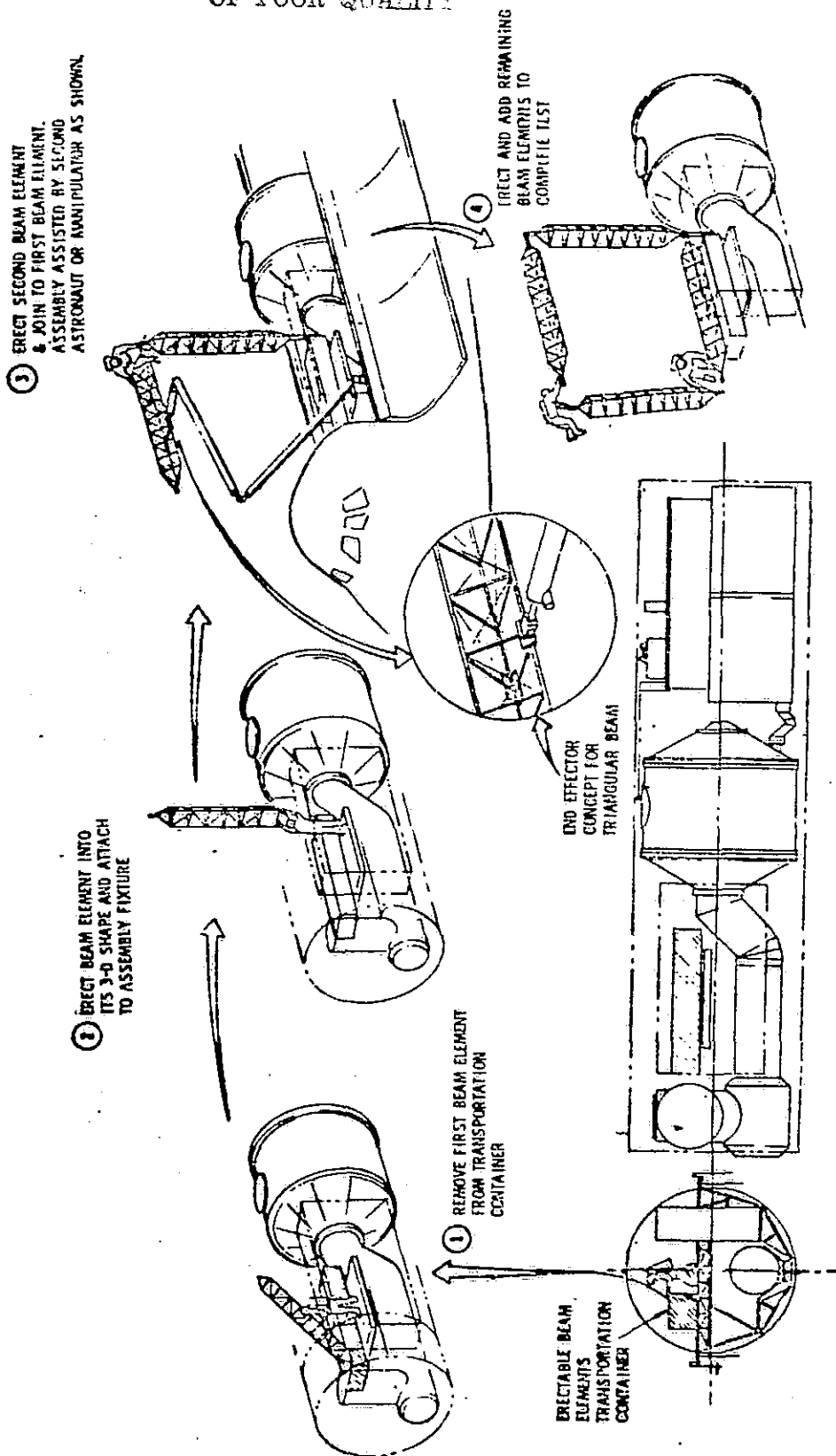


Figure 5-7. Assembly Sequence - Erectable Beam Tests



A plumbing diagram is shown in Figure 5-8. Each experiment involves four modes: (1) setup, including positioning of equipment (camera, heaters) and loading test fluid into the boiler; (2) warmup, in which the operating temperature and pressure are attained as steady-state conditions; (3) run, or the taking of photographic and other experimental data; and (4) shutdown, including cooling and depressurizing the boiler to ambient Spacelab module conditions, emptying the boiler, and stowing equipment.

Combustion Facility (ST-25)

The objectives are to examine in a near zero-g environment: (1)

Single Fuel Droplet Combustion - to

determine the rate of decay of the burning droplet radius and the physical and environmental conditions

where extinction takes place; (2) Flammability Limit of Premixed Gases -

to determine the propagation velocity of

the flame front, the velocity and temperature field while burning, and the conditions for extinction--particularly for fuel-lean mixtures; (3) Combustion in Fuel Particle Clouds - to determine the propagation velocity of the flame front through the cloud as well as conditions for ignition and extinction;

(4) Liquid Fuel Pool Burning - to determine propagation rates across the liquid surface as well as ignition and extinction criteria; and (5) Combustion of a Single Carbon Particle - to determine the rate of decay of the particle radius, the concentration and temperature field surrounding the particle, and ignition and extinction criteria.

The combustion facility will have a multipurpose capability. It requires portions of two opposite electronic instrument racks, and a double-wall combustion chamber (Figure 5-9). A cine camera with backlight is used to record data in conjunction with a HeNe laser, Photomultiplier tube, electronics, housing, frequency tracker, and bandpass filter to record data on a tape recorder. In addition, the experiment contains a control and display panel as well as O₂, N₂, and CH₄ gas supplies. The gas supplies are located in the pallet area for safety. The combustion products are vented overboard.

Geophysical Fluid Flow (ST-26)

The primary purpose of this experiment is to simulate the large-scale baroclinic geophysical fluid dynamics of the earth's oceans and atmosphere. The simulation will be accomplished via the use of a dielectric fluid confined between concentric rotating electrically conductive spherical shells.

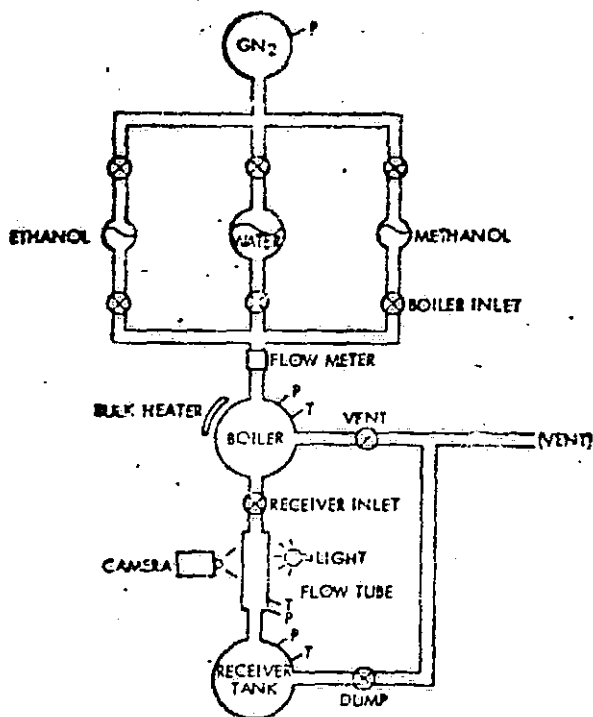


Figure 5-8. Plumbing Diagram of
Two-Phase Heat Transfer Facility

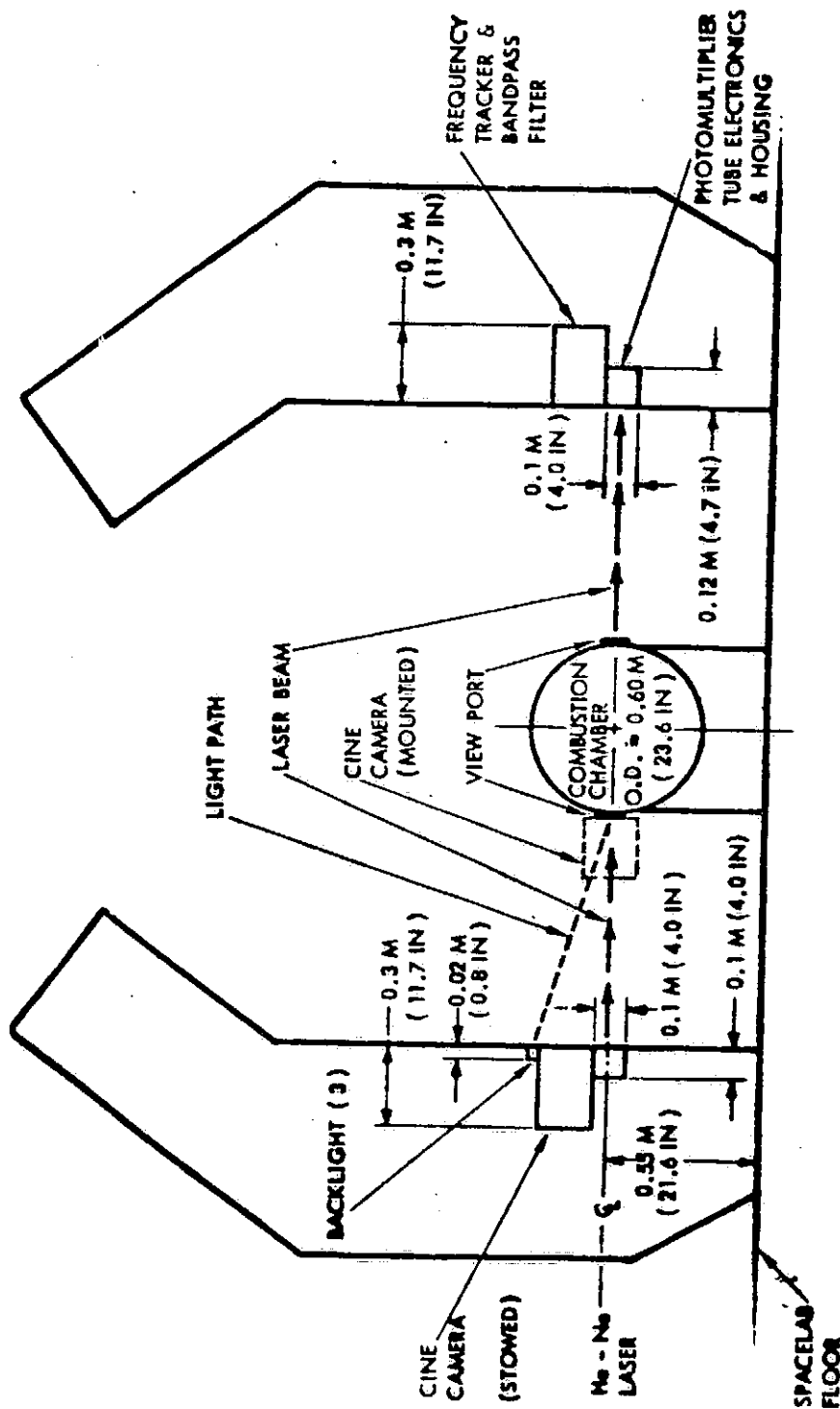


Figure 5-9. Combustion Facility Arrangement



The dielectric fluids will have a temperature-dependent dielectric constant so that upon application of a voltage between the spheres, an electric field will occur and a radially directed body force will act on the fluid in a manner exactly analogous to the gravitational body force which acts on the earth's oceans and atmosphere. This experiment will contain the correct vector relationship between the rotation vector and gravitational body force vector of the earth.

The experiment takes place in the upper hemisphere of a spherical capacitor, (Figure 5-10). Potential and temperature differences are applied across the electrical conducting inner and outer spheres. The inner and outer surfaces are also good thermal conductors. A temperature gradient can also be maintained along the inner and outer spheres between poles and equator.

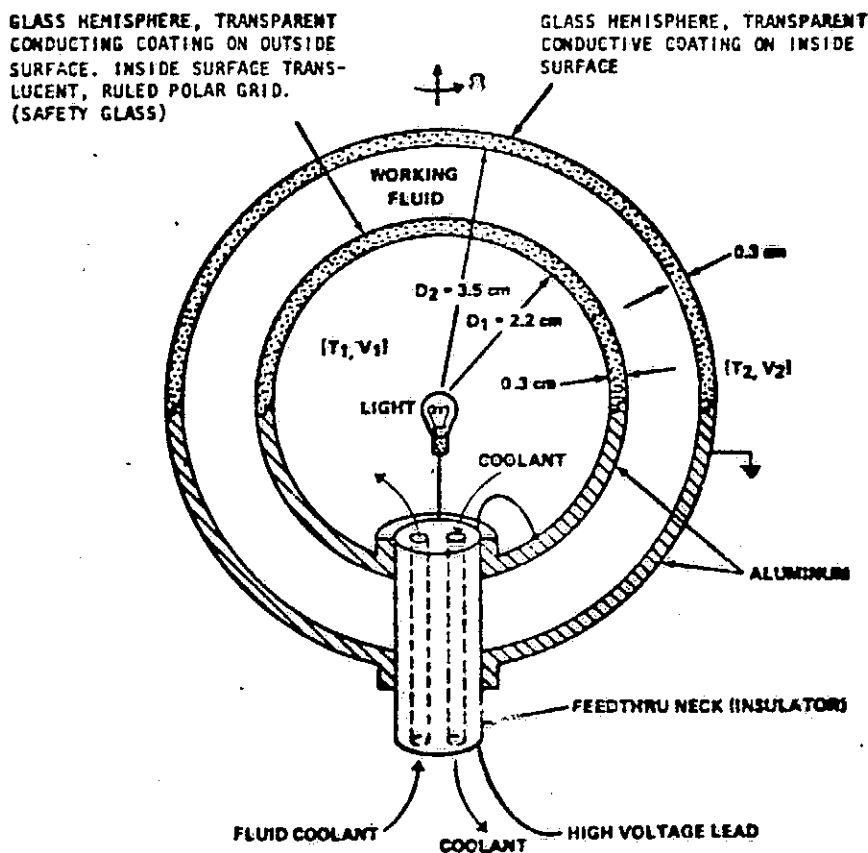


Figure 5-10. Electroconvection Cell

Flows are visualized by photographing a ruled grid on the inner electrode through the working fluid. Since the working fluid moves in response to thermal gradients, the accompanying index of refraction fluctuations will cause distortions in the lines.



Attitude Reference Determination System (X-2)

The principal objective is to develop and provide a precision (5 arc-sec) three-axis attitude reference in the Orbiter payload bay which can be used for precision instrument pointing and as a reference for evaluating the performance of advanced sensors. The instruments and sensors may either be co-located or remotely located with this experiment. The technology developed in this experiment will also be applicable to future unmanned spacecraft and as a standardized system for future Spacelab payloads.

Secondary objectives are to provide data on: (1) vehicle flexure effects between the Spacelab module, pallet, and the Orbiter Inertial Measuring Unit (IMU) due to gravitational unloading, thermal effects, crew motion, and Reaction Control System (RCS) firing; and (2) stray light rejection in the visible light region to supplement data from NG-3.

The attitude reference determination system provides a more precise attitude reference than is available at the Orbiter IMU, and compensates for vehicle flexure effects by being either (1) co-located with an experiment, or (2) directly linked by an autocollimator. A real-time attitude determination capability is provided on-board. An electrical interface is provided for experiments which require accurate attitude and rate data for the operation of the experiments. Data are recorded for post-flight reconstruction in support of other experiments.

A strapdown inertial reference unit (IRU) which contains three rate gyros provides a short-term inertial reference. Periodic stellar updates from either of two strapdown star trackers are used to bound the long-term gyro drift. An autocollimator is used to obtain three-axis relative orientation between this system and a remote payload. A retroreflector is installed on the remote payload package to return two light beams to their source where a segmented detector array senses the relative deflections in three axes. A precision mounting plate is used to co-mount the IRU, star trackers, and autocollimator to provide a stable reference. Movable mirrors may be placed in the two beam paths to direct the beams to several experiments (one at a time).

Experiment X-2 will be used primarily to support earth-oriented experiments. This poses star tracker interference problems due to the sun, earth, albedo, and glint. In addition, the star tracker field of view is restricted by the payload bay doors and the subtended earth. The compromise solution, as shown in Figure 5-11, is to roll the Orbiter 15 degrees (right wing is below the horizon) during the earth local vertical operations. The star tracker boresight is elevated 10 degrees above the Orbiter XY-plane.

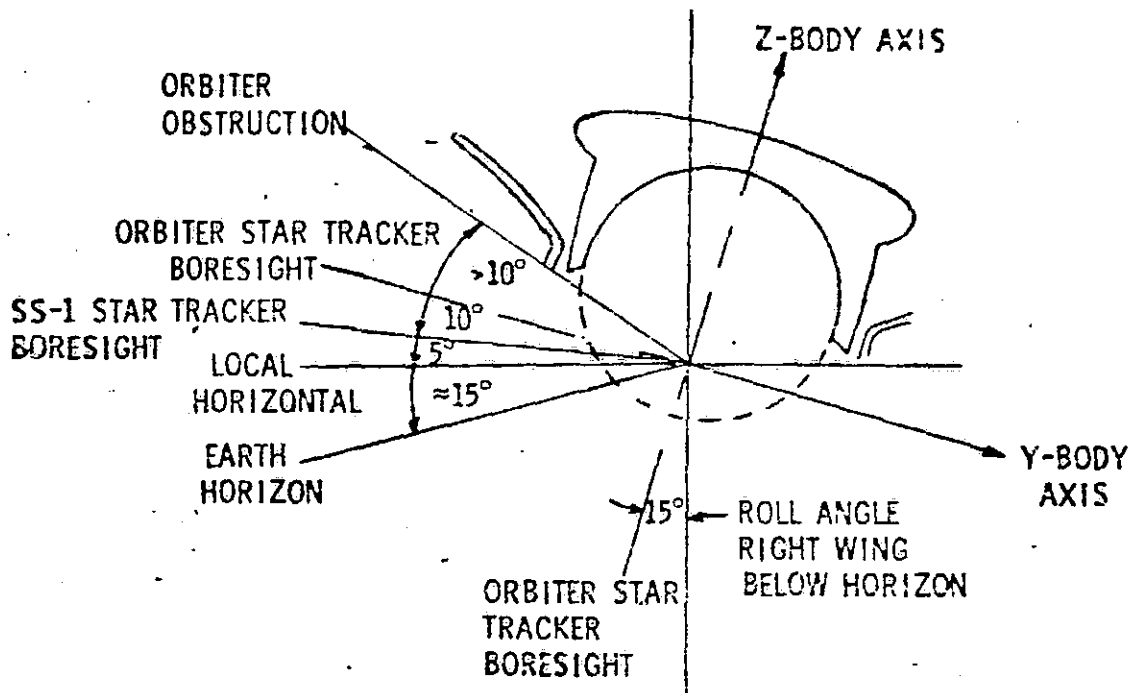


Figure 5-11. Star Tracker Geometry

PAYLOAD CONFIGURATION

In order to develop realistic estimates of the installation and checkout tasks required in Level IV integration experiment component layouts, wiring diagrams, and fluid line routings were developed for the ATL payload. These configuration drawings were synthesized from the detailed end item data and functional interface diagrams for each of the experiments. The data for the individual experiments are presented in GPREDP's in Appendix D.

Component Layouts

A list of the ATL payload end items is presented by experiment in Table 5-2. The forward support structure (FSS) items for SF-2, AFD equipment for SF-1, and FSS and AFD equipment for ST-16 B will be installed in the Orbiter in the Orbiter Processing Facility (OPF) (Level I integration). All other end items will be installed and verified during Level IV integration.

A layout of the cargo bay equipment is shown in Figure 5-12. Callouts on each assembly refer to the experiment and end item defined in the GPR EDP's. A perspective layout of the pallet-mounted equipment is presented in Figure 5-13. Views with and without the Microwave Radiometer assembly (ST-10) installed are shown.



Table 5-2. ATL Experiment End Items

Experiment	End Item	Nomenclature	Location
SF-1	1	Strapdown IMU	PSS, AFD
	2	Digital Computer	
	3	Input/Output Controller and Display	
	4	IMU Interface Electronics	
	5	Power Supply	
	6	Digital Tape Recorder	
SF-2	1	Manipulator	Forward Support Structure (FSS), Cargo Bay
	2	Remote Electronics Power Unit	
	3	Docking Adaptor	
	4	TV Camera A	
	5	TV Camera B	
	6	TV Camera C (Stereo)	
	7	Task Board	
	8	Control Panel A	Habitable Module
	9	Control Panel B	
	10	Hand Controllers and Storage	
	11	Video Recorder (Shared)	
	12	Data Recorder (Shared)	
	13	Telemetry/Command Unit	
ST-1	1	Experiment Module	Habitable Module
	2	Camera	
	3	Oscilloscope	
	4	Digital Voltmeter, Com- puter and Spectrum Analyzer	
	5	Sequencer and Display	
	6	Power Conditioning Equipment	
	7	Isolating Racks With Transpar- ent Sliding Doors (Container of all end-items)	
	8	Storage Compartments	
	9	System Controls	
	10	Experiment Module Compart- ment	
	11	Film Magazines	



Table 5-2. ATL Experiment End Items (continued)

Experiment	End Item	Nomenclature	Location
ST-2	1	Ambient Air Monitor	Pallet #1
	2	Orbital Environment Monitor	
ST-3	1	Optical Bench and Base	Pallet #2
	2	Dual Telescope Assembly	
	3	Scan Mirror Assembly	
	4	Gas Cell Turret	
	5	Tunable Laser Battery	
	6	Detector	
	7	Tunable Laser Refrigerator	
	8	Detector Cooler	
	9	Tunable Laser Programmable Power Supply	
	10	Signal Processor	
	11	Scan-and-Track Controller	Habitable Module
	12	TV Camera	Pallet #2
	13	Experiment Power Supply	
	14	Black Body	
	15	Digital Tape Recorder	Habitable Module
ST-5	1	Radiometer	Pallet #2
	2-6	Electronics Module	
	2	Power Conditioner	
	3	Temperature and Cryogenic Control	
	4	Caution and Warning	
	5	Command Interface	
	6	Data Interface	
	7	Tape Recorder	Habitable Module
	8	Cryogenic Tank and Plumbing	Pallet #2
ST-10	1	L/S-band Antenna Assembly	Pallet #1
	2	C/X-band Antenna Assembly	
	3	K-band Antenna Assembly	
	4	L/S-band RF Enclosure	
	5	C/X-band RF Enclosure	
	6	K-band RF Enclosure	
	7	L/S-band Main Control Unit	



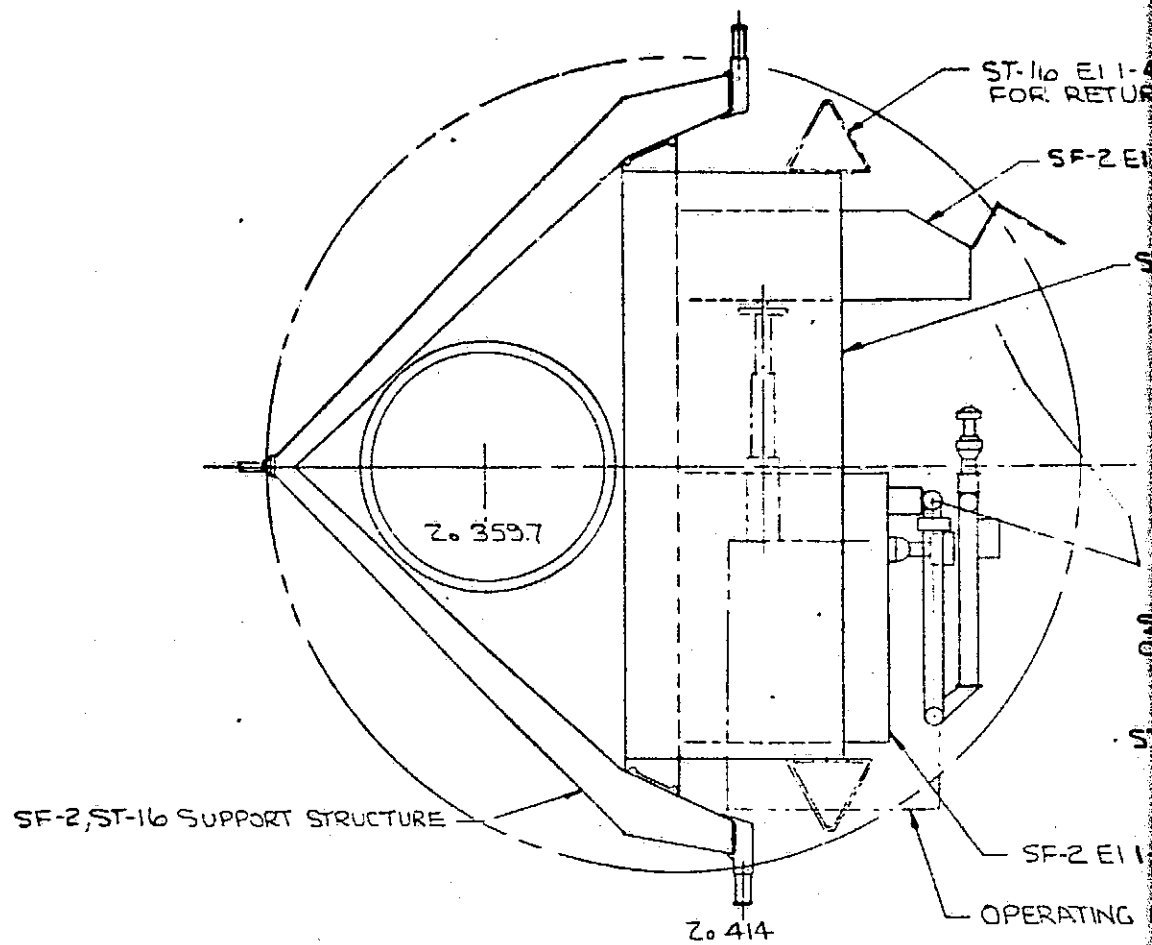
Table 5-2. ATL Experiment End Items (continued)

Experiment	End Item	Nomenclature	Location
ST-10 (Cont.)	8	C/X-band Main Control Unit	Pallet #1
	9	K-band Main Control Unit	
	10	L/S-band Auxiliary Unit	
	11	C/X-band Auxiliary Unit	
	12	K-band Auxiliary Unit	
	13	Digital Recorder (Shared)	
	14	Control and Display Panel	Habitable Module
	15	Antenna Support Assembly	
ST-16B	1-4	Erectable Structural Element B	FSS, Cargo Bay
	5	Transportation Container	
	6	Assembly Pedestal	
	7	RMS End Effector	
	8	Tape Recorder	PSS, AFD
	9	Control/Display Panel/Module	
	10	Video Recorder	
ST-20	1	Solar Cell Test Plate	Boom, Pallet #2
	2	Solar Tracking and Processing Electronics	
	3	Deployment Boom	Pallet #2
	4	Deployment Boom Drive Motor	
	5	Control/Display Panel/Module	Habitable Module
	6	Digital Tape Recorder	
ST-21	1	Boiler	Habitable Module
	2	Test Heater	
	3	Bulk Heater	
	4	Radiant Heater	
	5	Flow Tube	
	6	Plumbing and Regulation	
	7	Tape Recorder	
	8	Data Handling	
	9	Cine Camera	
	10	Lights	
	11	Control/Display Panel/Module	
	12	Receiver tank	
	13	Water Container	
	14	Alcohol Container	



Table 5-2. ATL Experiment End Items (continued)

Experiment	End Item	Nomenclature	Location
ST-25	1	Combustion Chamber	Habitable Module
	2	Cine Camera	
	3	Camera Backlight	
	4	O ₂ and N ₂ Supply and Fill	
	5	CH ₄ gas supply and fill	
	6	Control/Display Panel/Module	
	7	He-Ne Laser	
	8	Photomultiplier Tube, Electronics, and Housing	
	9	Frequency Tracker	
	10	Bandpass Filter	
	11	Tape Recorder and Data Handling	
ST-26	1	Fluid Flow Module	Habitable Module
	2	Control/Display Panel/Module	
X-2	1	Inertial Reference Unit	Pallet #2
	2	Star Tracker	
	3	Star Tracker Sun Shield	
	4	Digital Computer	
	5	Mounting Plate	
	6	Tape Recorder	Habitable Module
	7	Control and Display Panel	

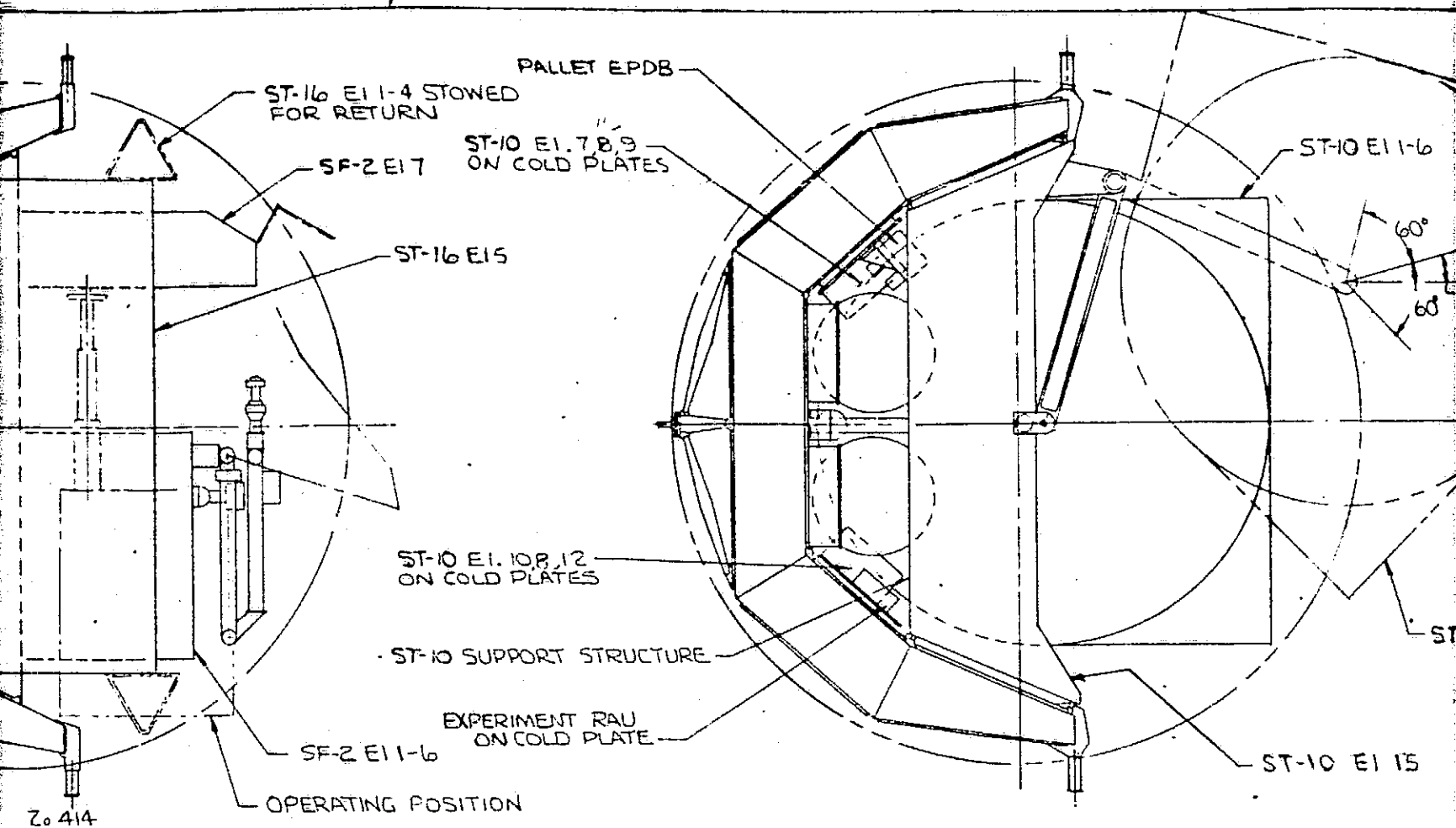


SECTION A-A

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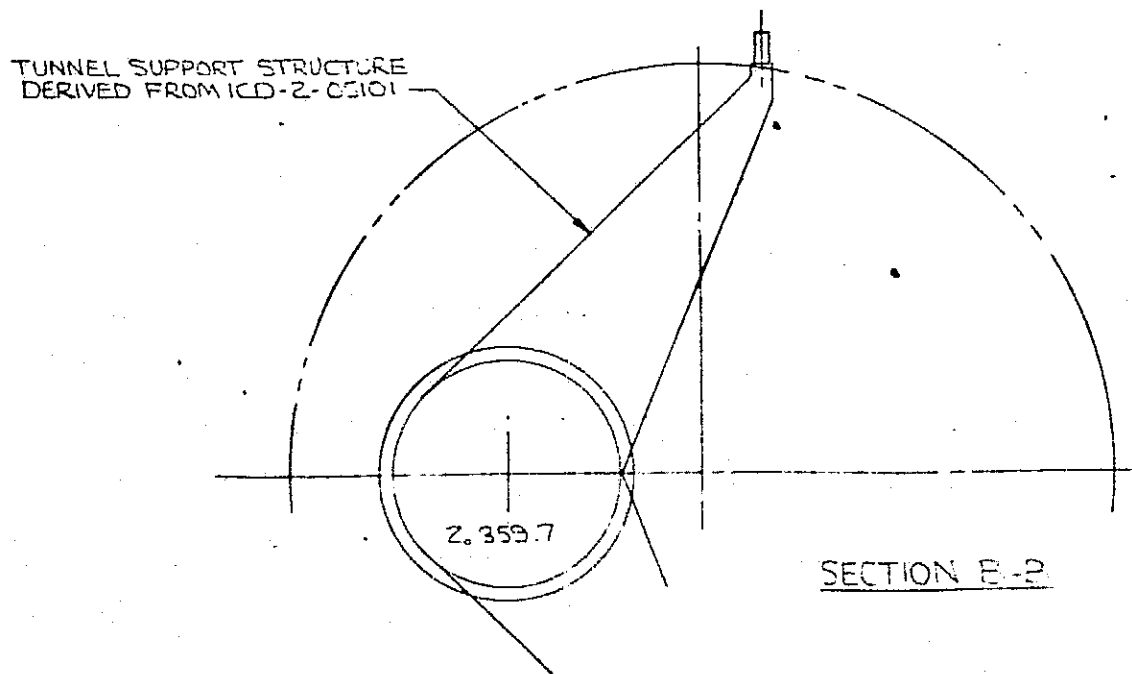
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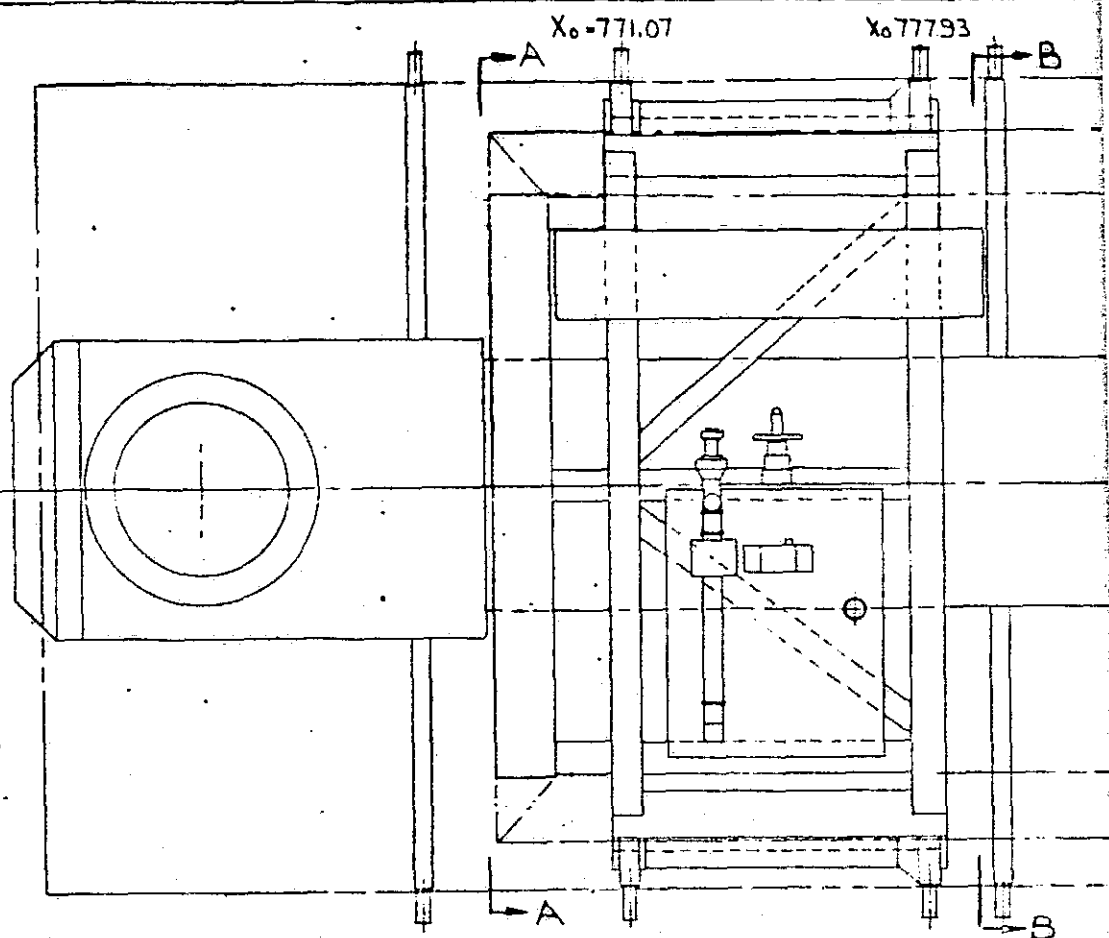
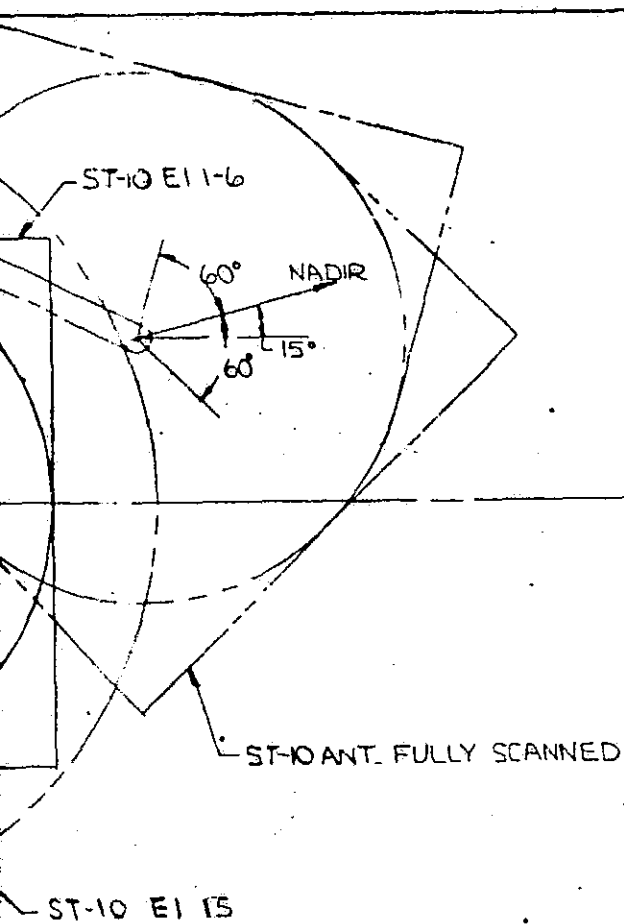


SECTION A-A

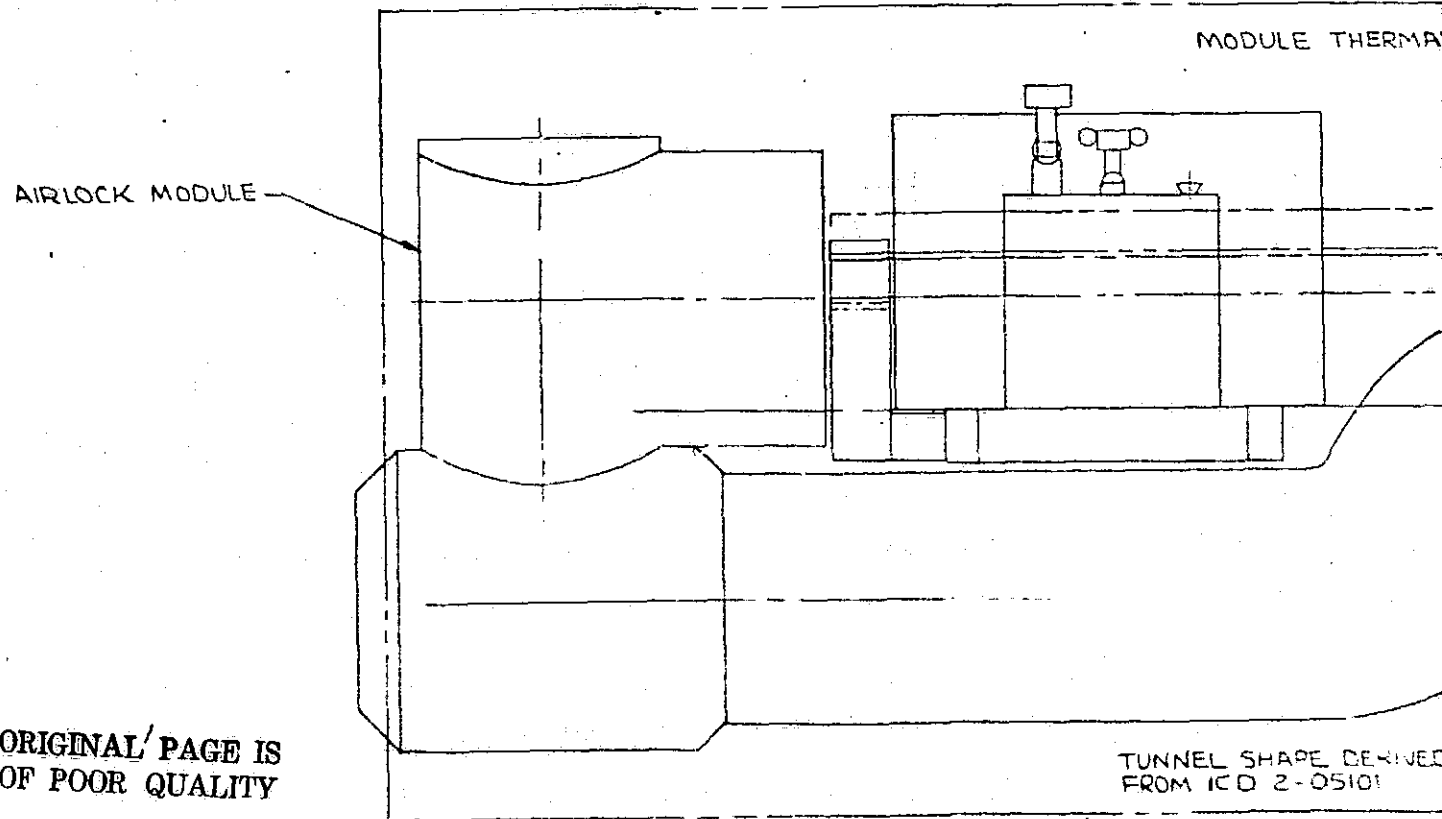
SECTION C-C



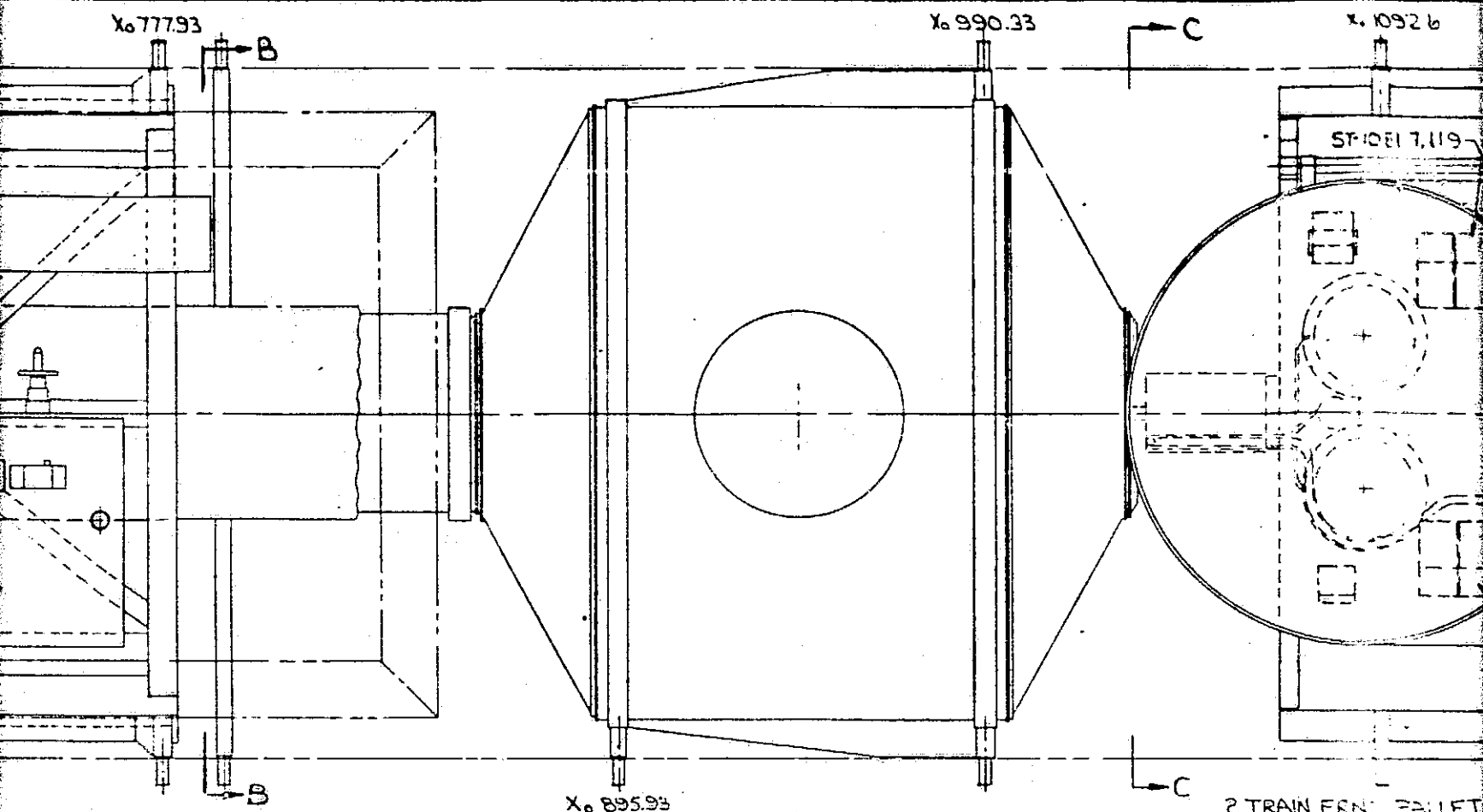
SECTION E-2



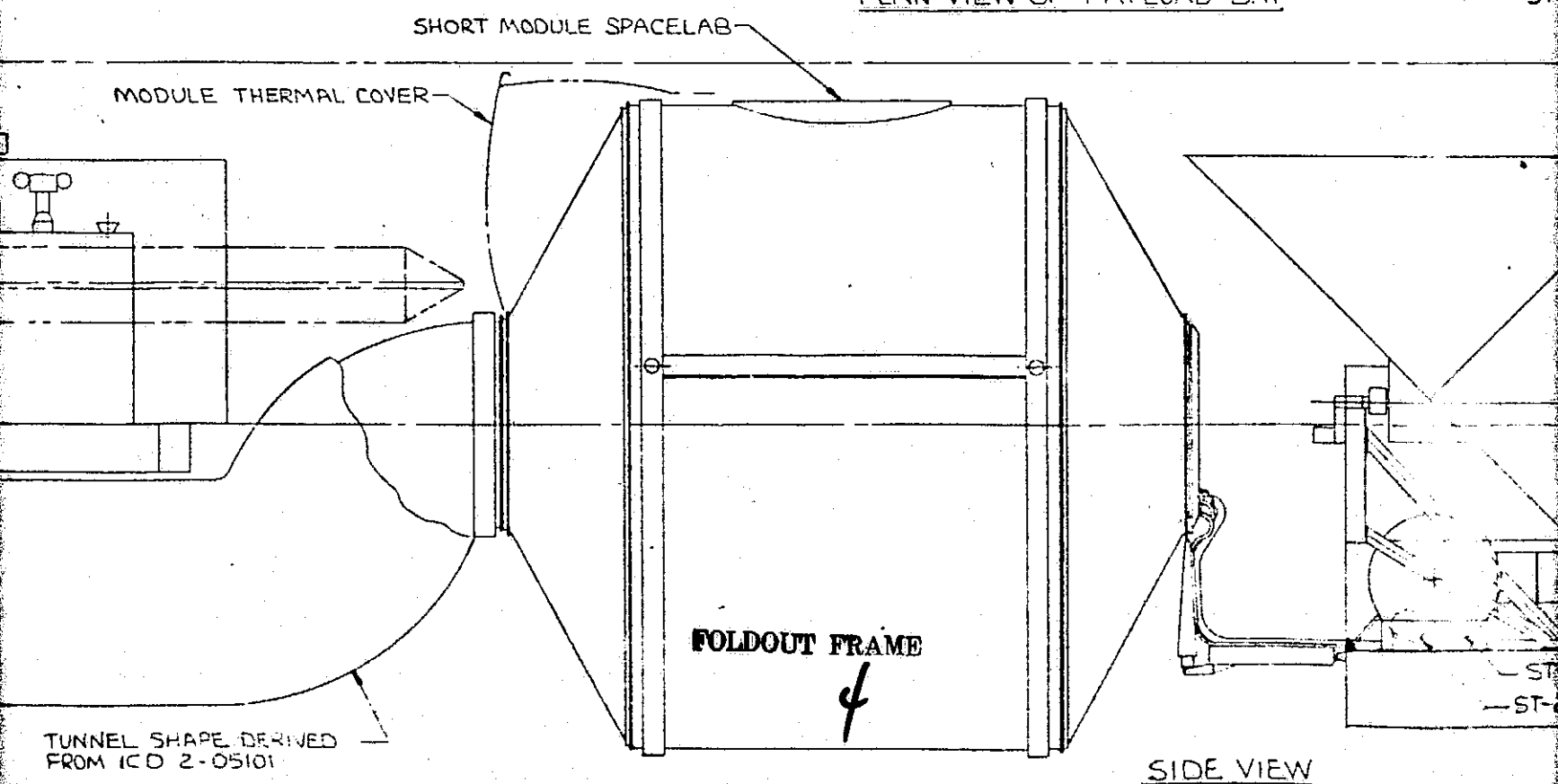
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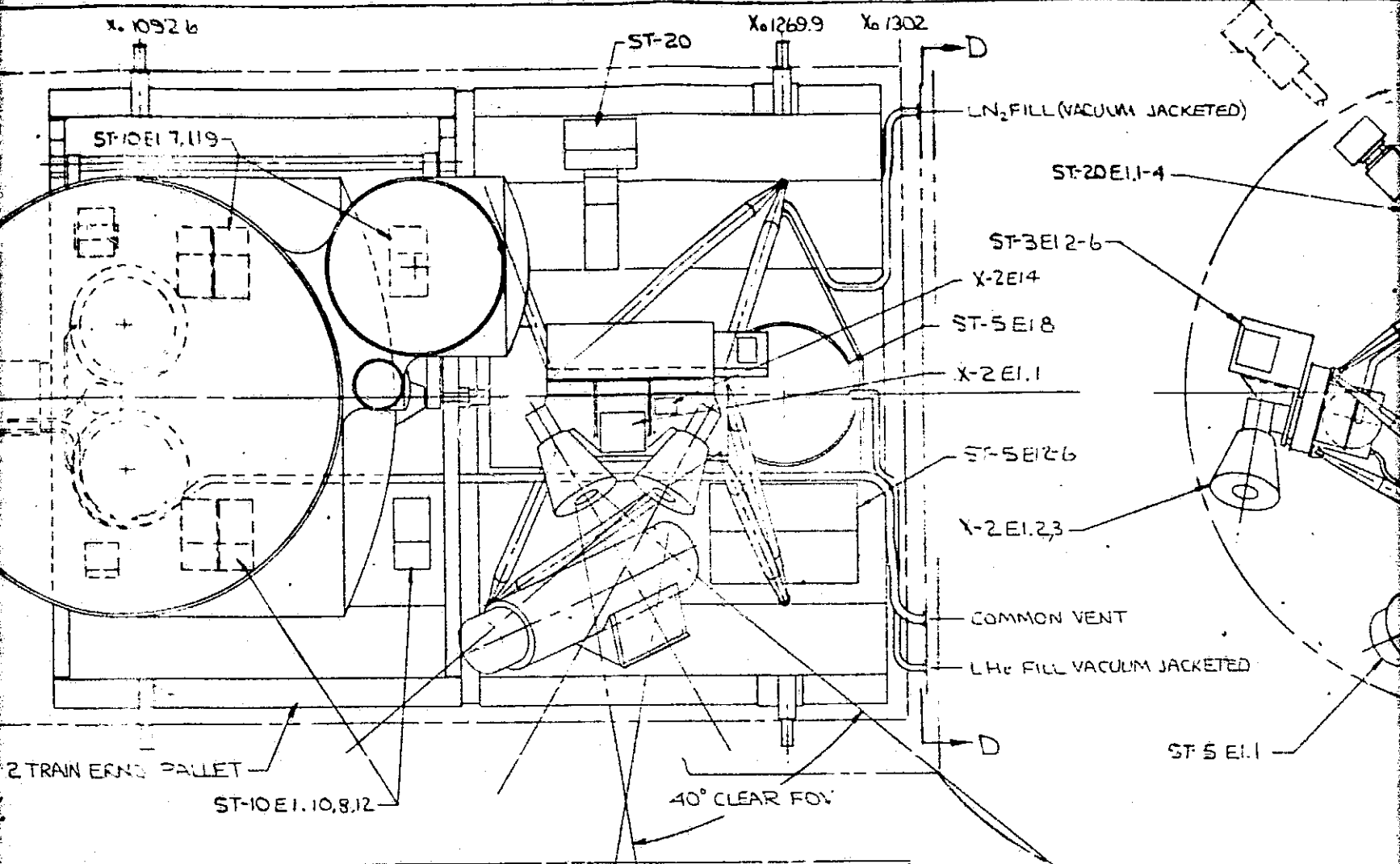
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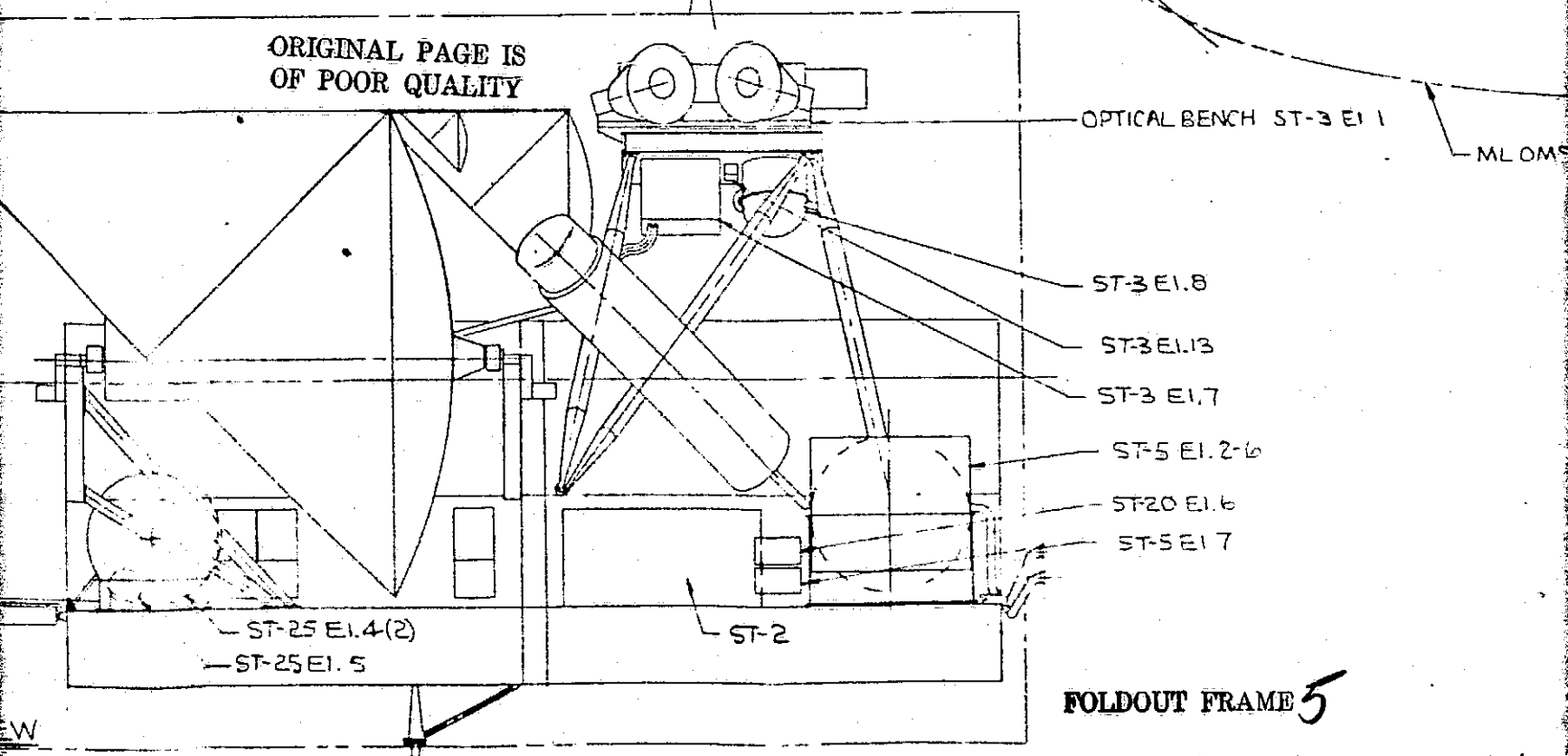
PLAN VIEW OF PAYLOAD BAY



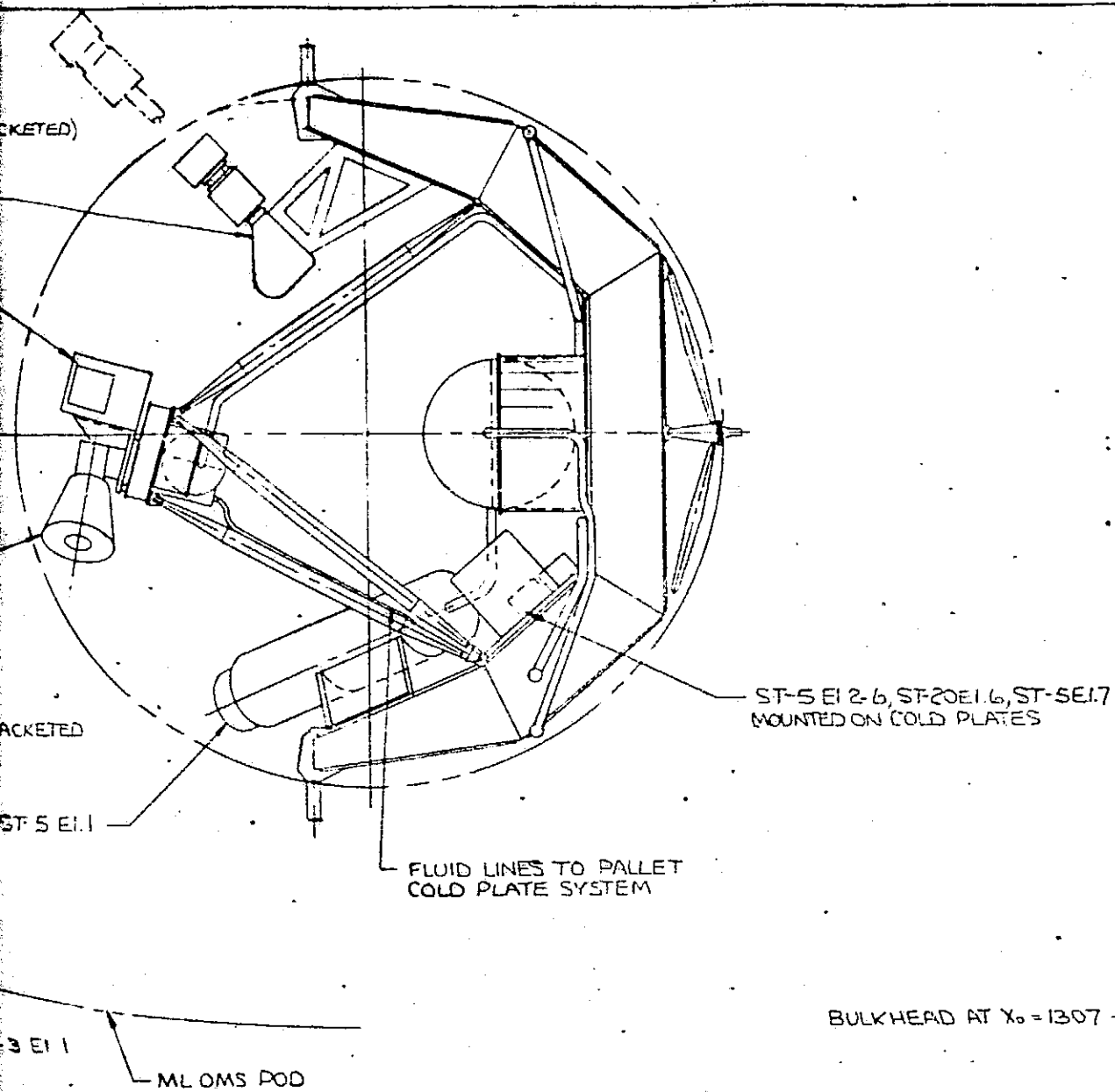
SIDE VIEW



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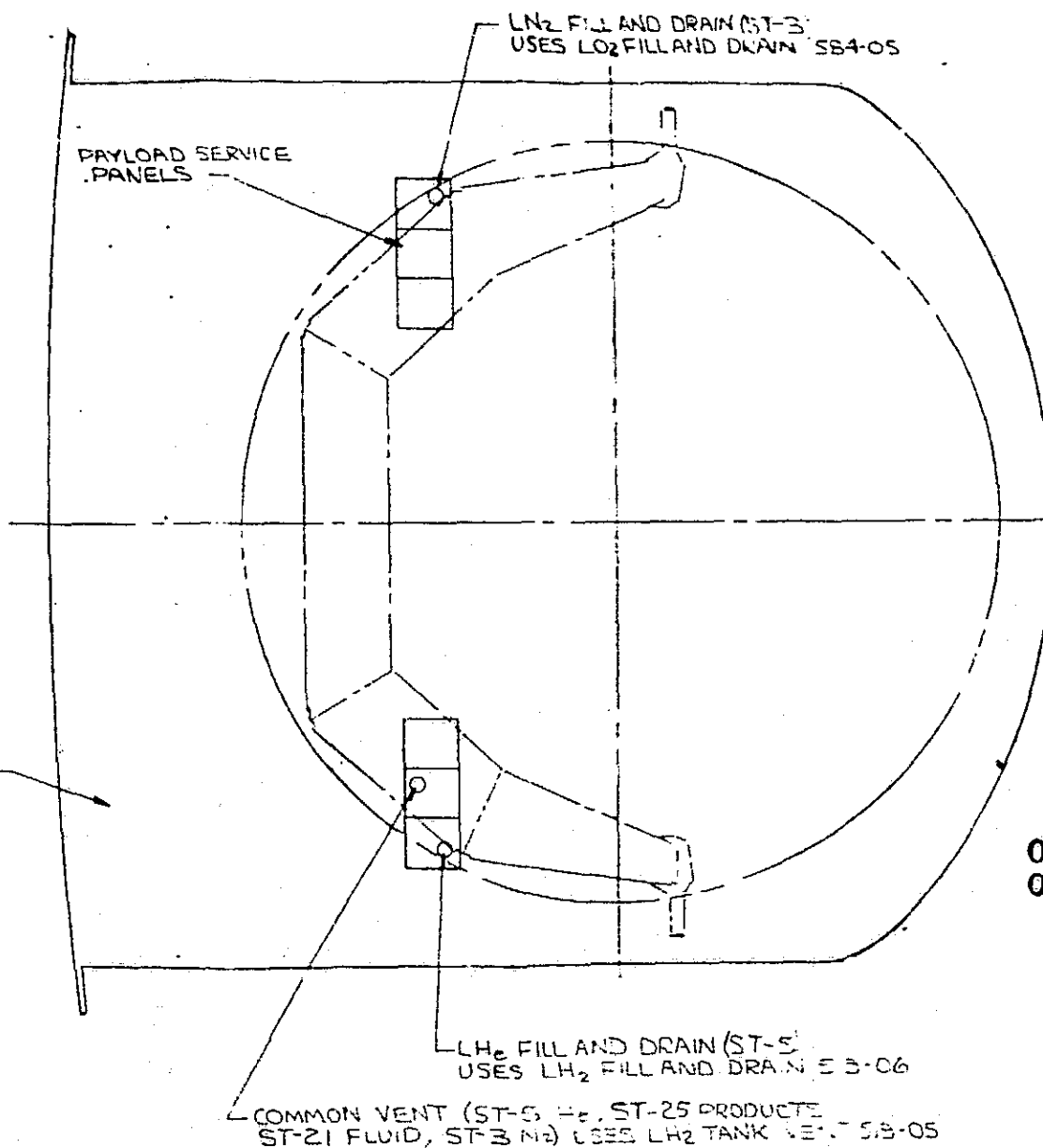
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PAYLOAD SERVICE
PANELS

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ST-21 FLUID

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VIEW D-D

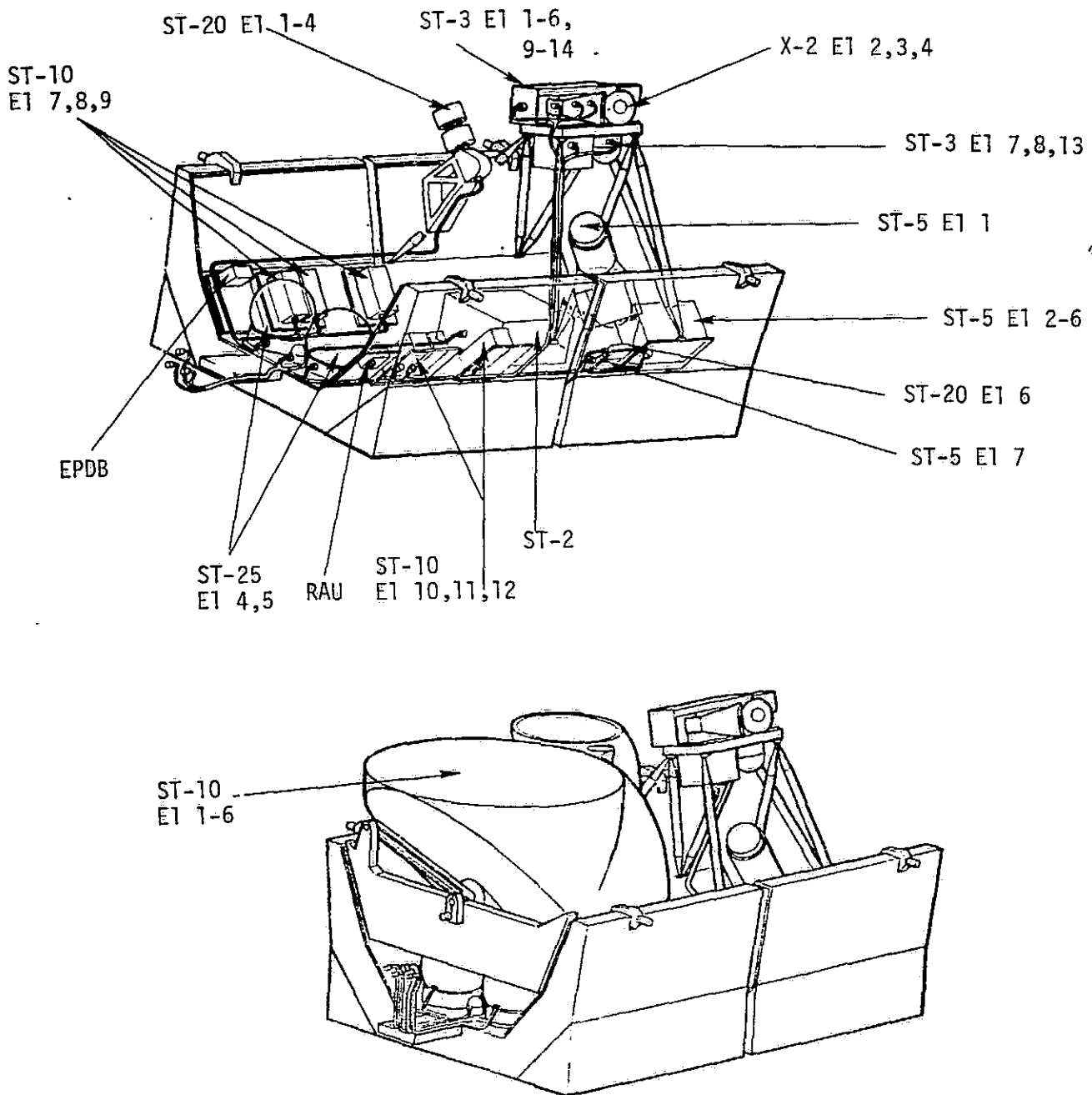
Figure 5-12. ATL Experiment Installation Layout
in the Cargo Bay

5-23, 5-24

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DRAWING 120	ROCKWELL INTERNATIONAL CORPORATION SPACE DIVISION 1111 LAFAYETTE AVENUE, SUITE 100, CARLSBAD, CALIFORNIA
PAYLOAD A INSTALLATION ATL STUDY	
2511-25	

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Figure 5-13. Pallet Mounted Equipment Layout-ATL



A perspective of the forward support structure assembly which would be integrated during Level IV activities is shown in Figure 5-14. FSS installation over the tunnel is also shown in Figure 5-14.

The base of the cradle will be installed prior to tunnel installation. After installation of the tunnel and Spacelab module-pallet train the SF-1 and SF-2 equipment assembly is installed on the cradle.

A layout of the ATL payload equipment to be mounted in the habitable module is presented in Figure 5-15. Side views are included to illustrate the clearance within the racks for cabling and cooling ducts. The installation of the combustion chamber on the module floor, and the fluid line interfaces with the aft bulkhead of the module are also shown.

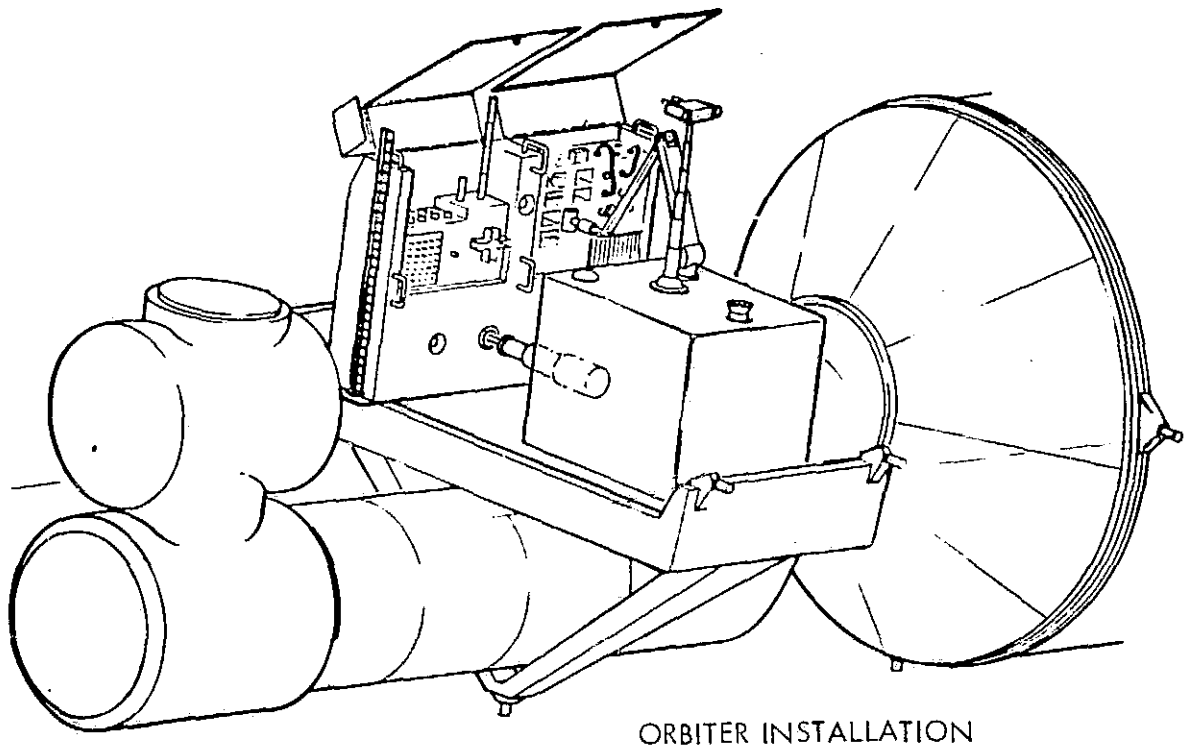
The AFD equipment installation is illustrated in Figure 5-16. Spacelab subsystem controls are shown for reference only. In addition to command/telemetry functions some of the ATL experiments use the Spacelab CDMS for experiment operations and/or real time data display.

Payload Cabling

An integrated payload functional interface schematic was developed. Interconnections between experiment end items and experiments and Spacelab support equipment were identified. Interconnection requirements on the pallet train are indicated in Figure 5-17. Module requirements are shown in Figure 5-18. Cable paths and approximate lengths of each cable were developed. These cable harnesses are summarized in Table 5-3. The cable harnesses were the basis for estimation of the wiring installation tasks that are defined in Volume II.

Fluid Lines

A layout similar to the electrical interconnections was developed for the fluid line interconnections. A list of the various ATL payload fluid interconnections is presented in Table 5-4. Note that cold plate interconnections on the pallets are not included. Coldplate installation and interconnections activities are part of staging operations at KSC.



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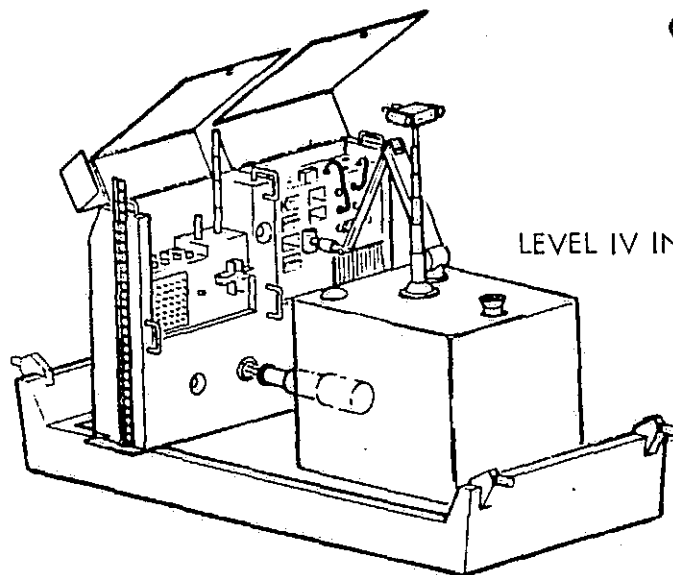
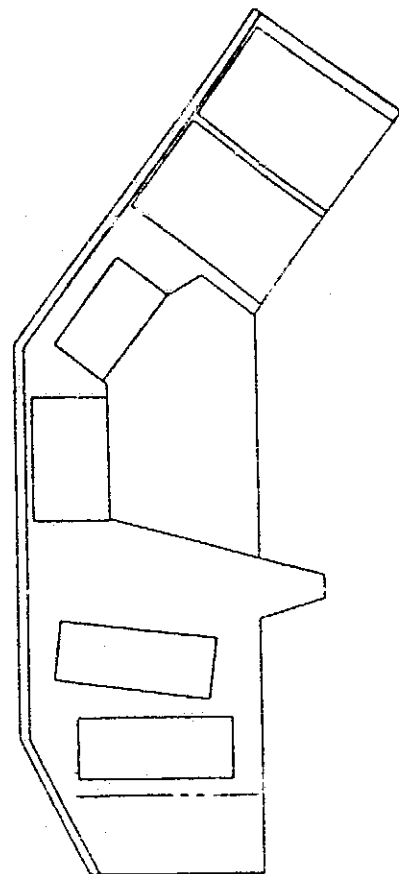


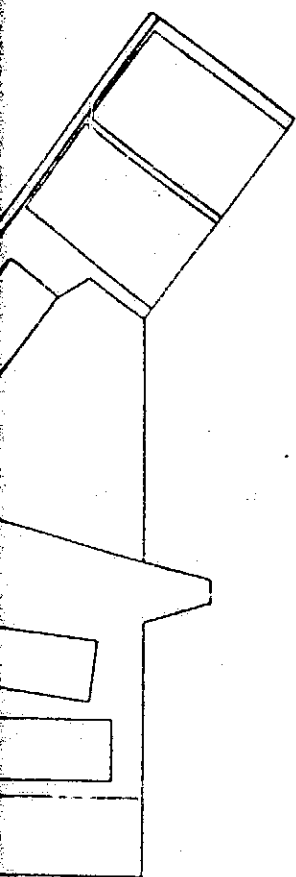
Figure 5-14. Forward Support Structure Assembly (ATL Payload)

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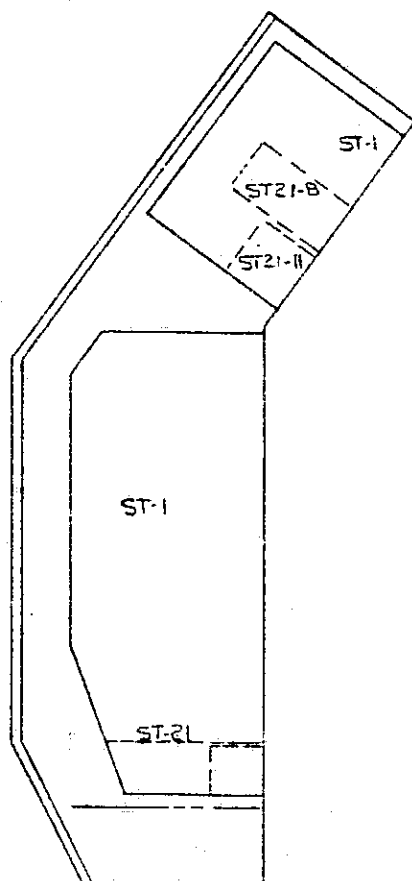


VIEW F-F

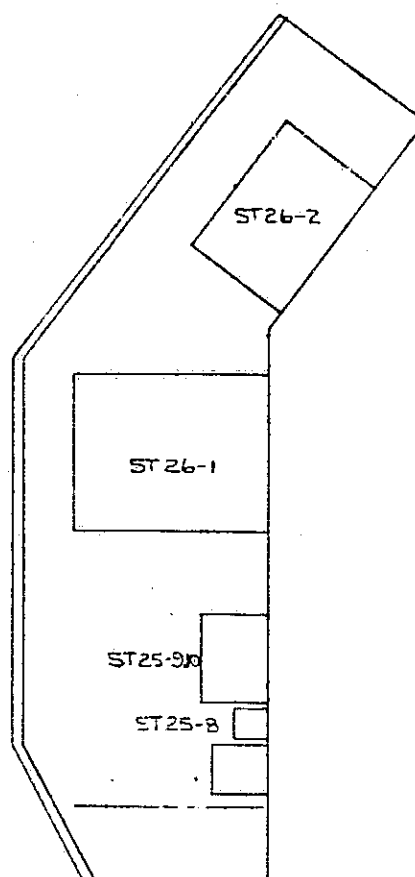
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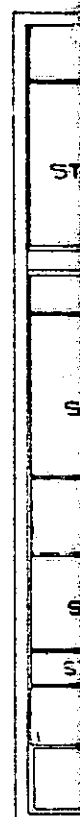


VIEW E-E



VIEW D-D

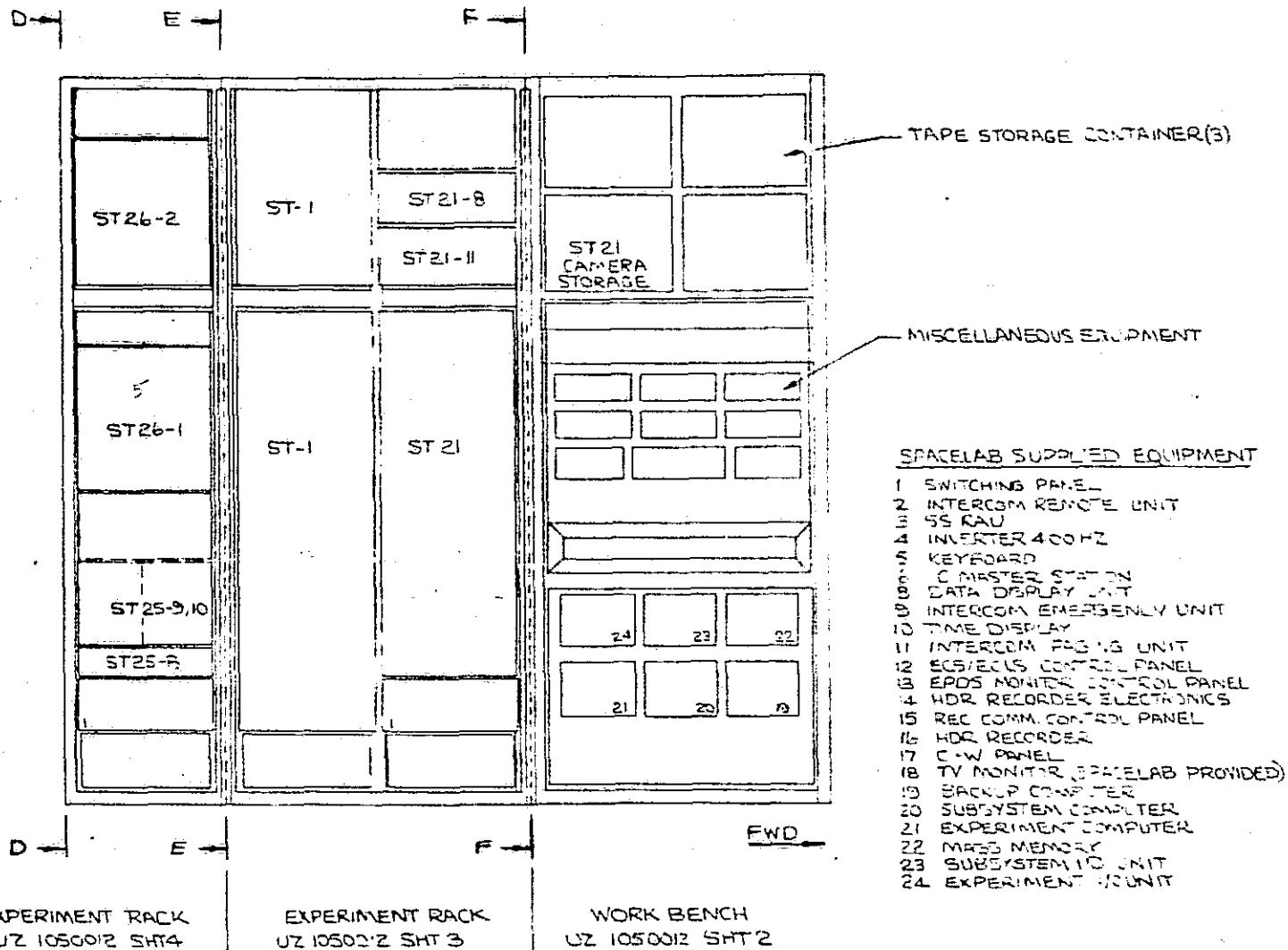
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EXPERIMENT
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VIEW ON LEFT HAND RACK

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TAINER(3)

MPMENT

EQUIPMENT

UNIT

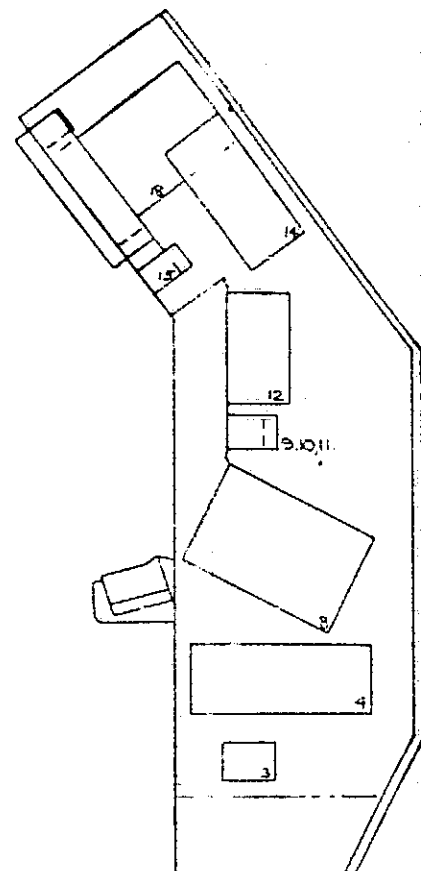
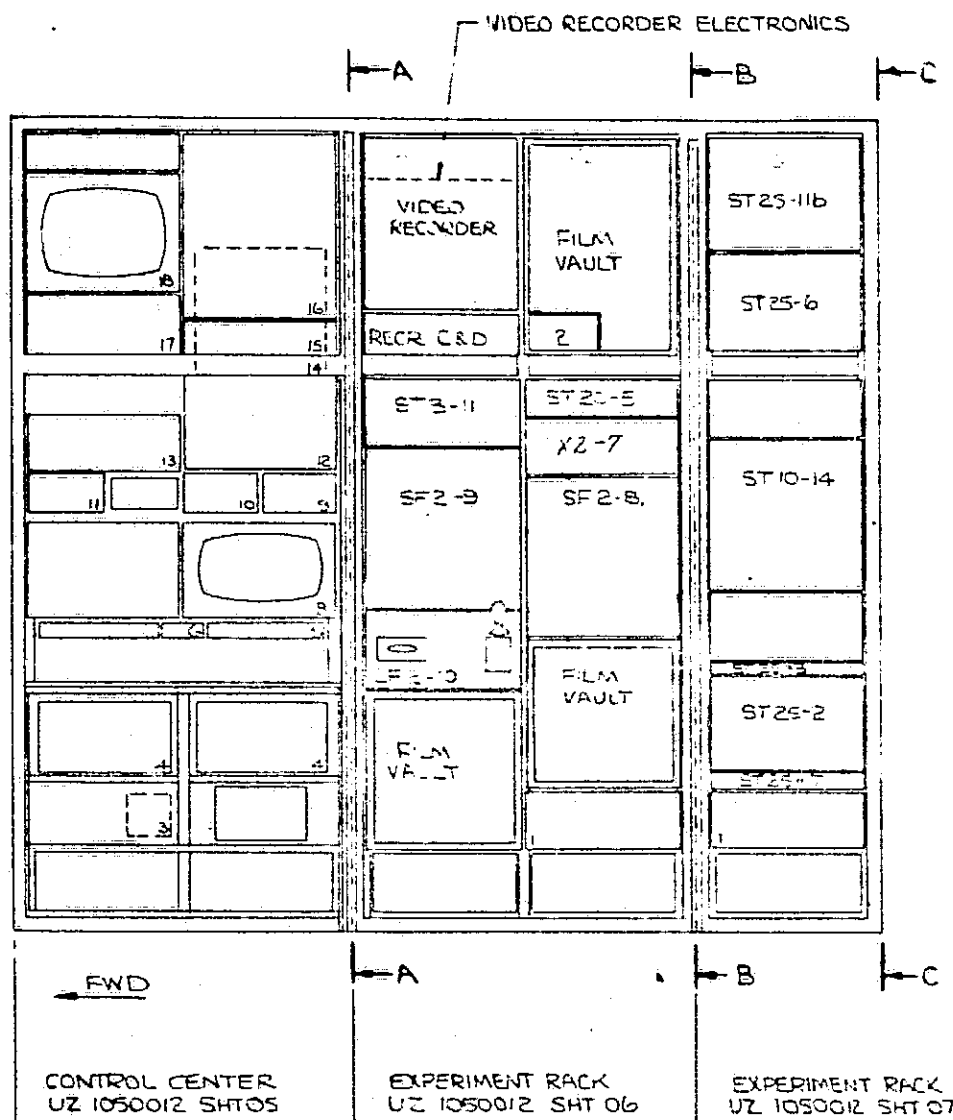
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PANEL
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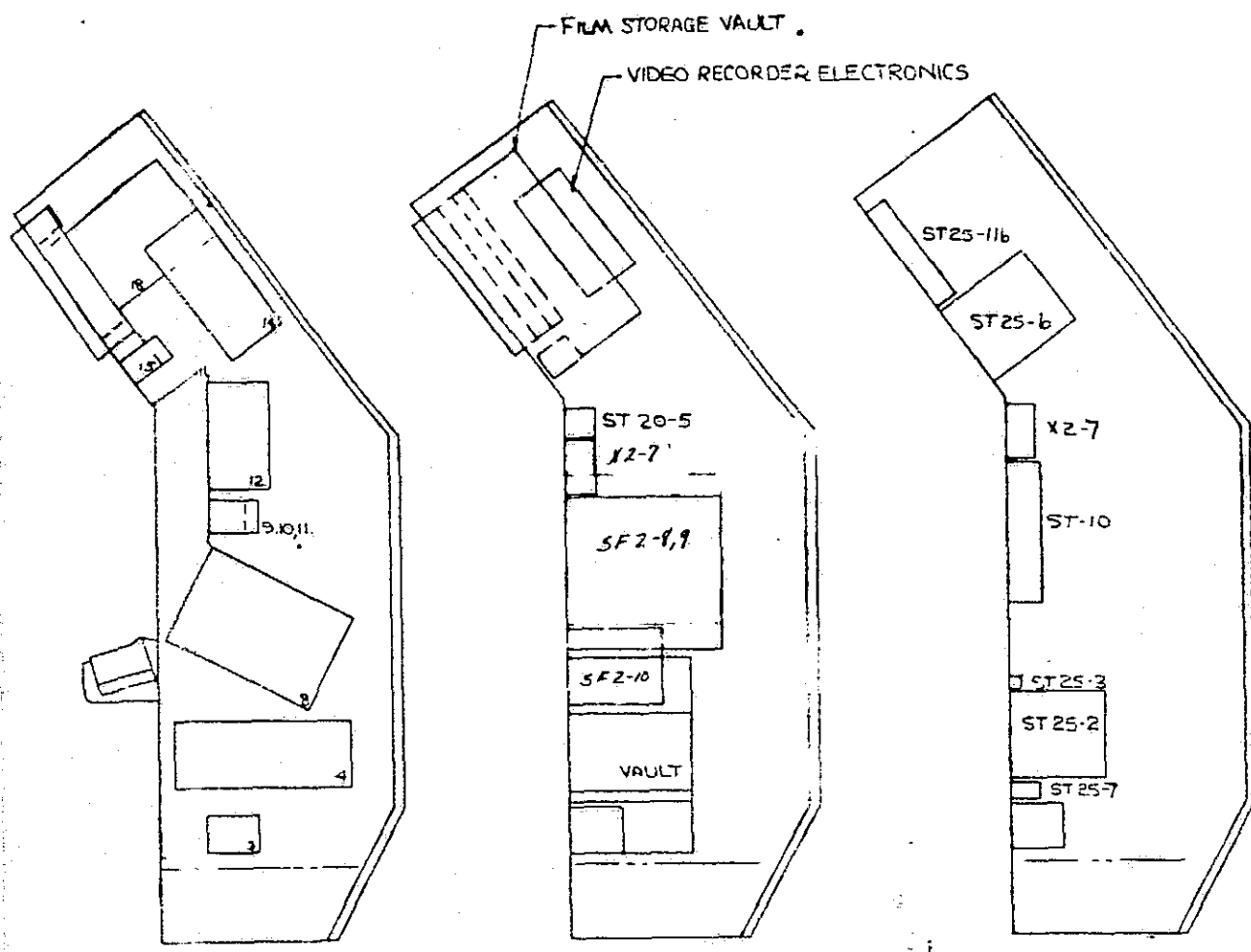
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VIEW ON RIGHT HAND RACK

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VIEW A-A

VIEW B-B

VIEW C-C

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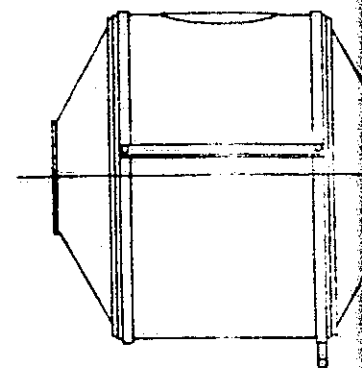
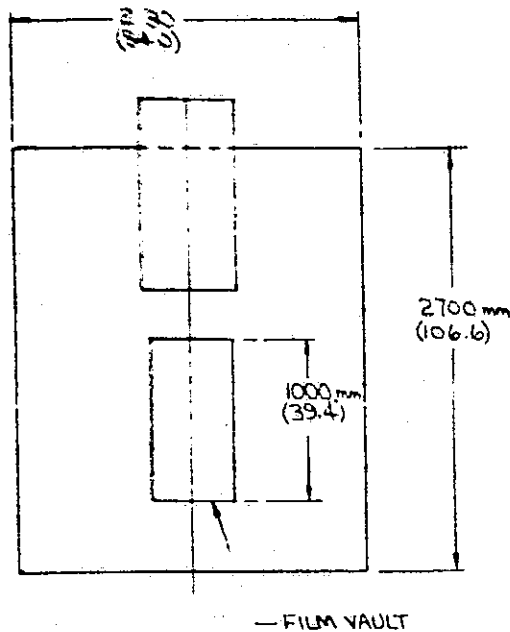
VENT LINE TO BR-
ATTACHED TO REAR
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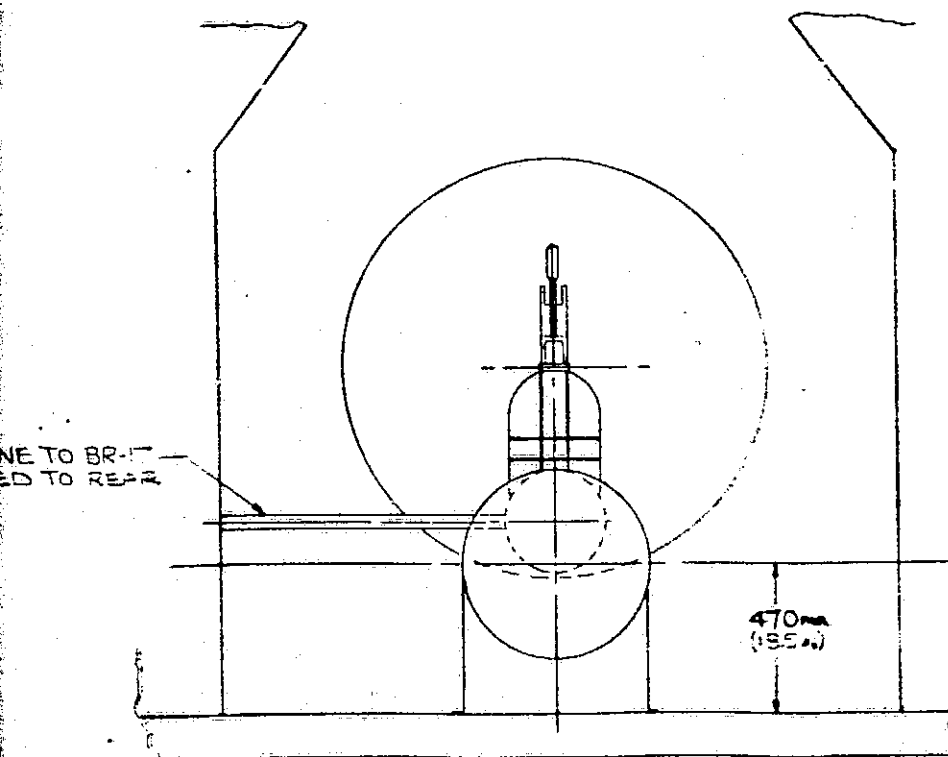


ST-25-1

SPACELAB FLOOR



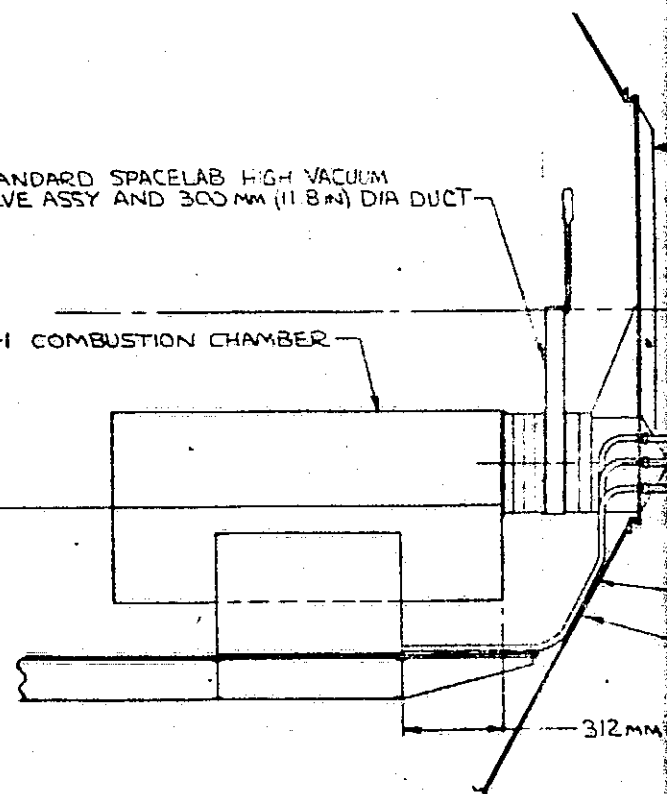
VIEW G-G
SCALE 20



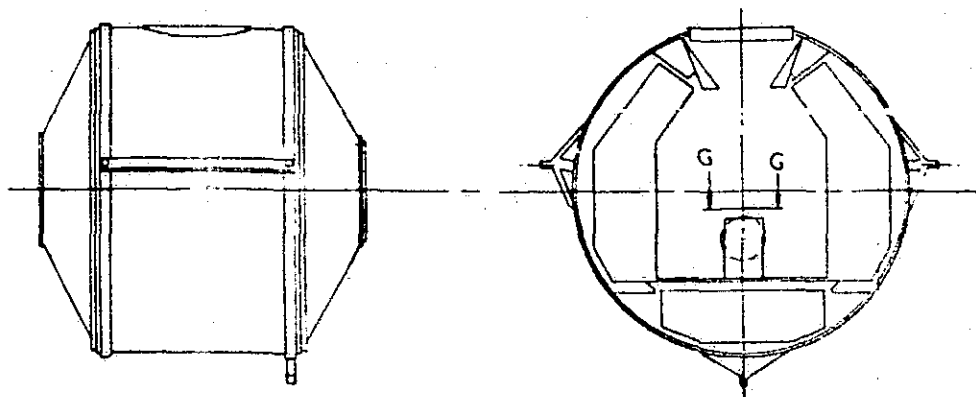
VIEW LOOKING AFT
SHOWING ST25-1 MOUNTED
ON SPACELAB FLOOR

STANDARD SPACELAB HIGH VACUUM
VALVE ASSY AND 300 MM (11.8 IN) DIA DUCT

ST25-1 COMBUSTION CHAMBER

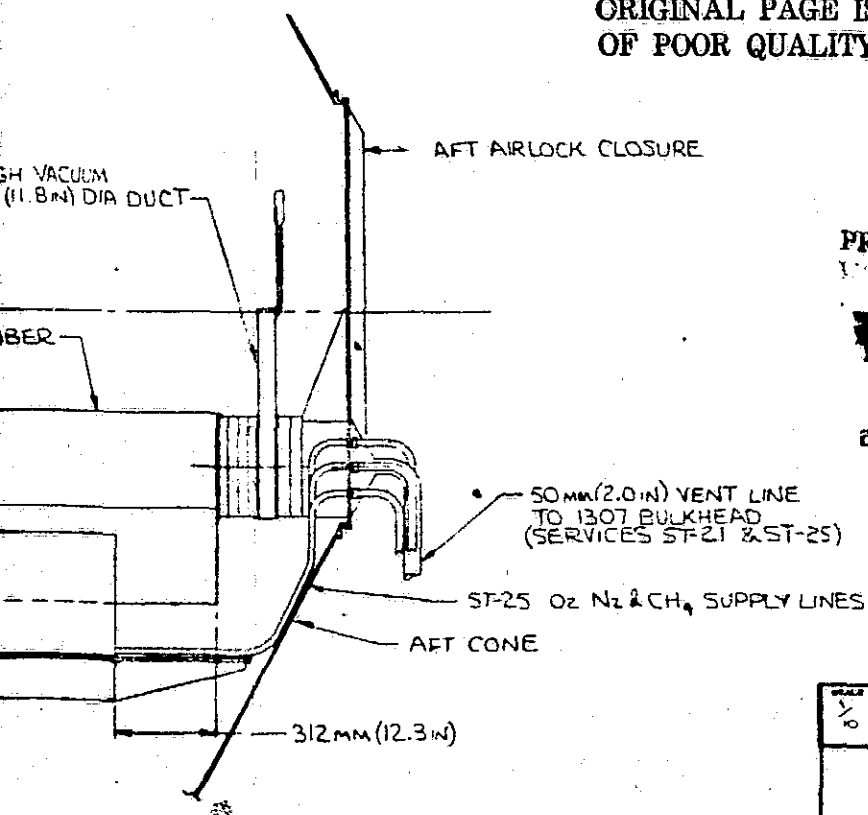


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SHORT MODULE SPACELAB

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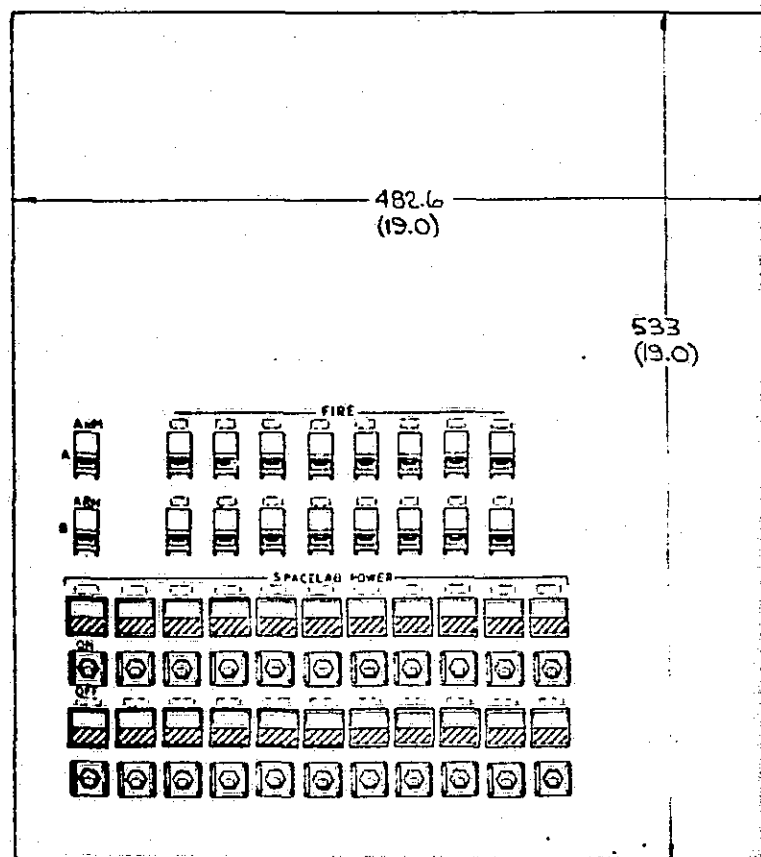
Figure 5-15. ATL Installation Layout in the Spacelab Module

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SPACELAB ACCOMMODATION PAYLOAD A ATL STUDY			2511-24

5-29, 5-30

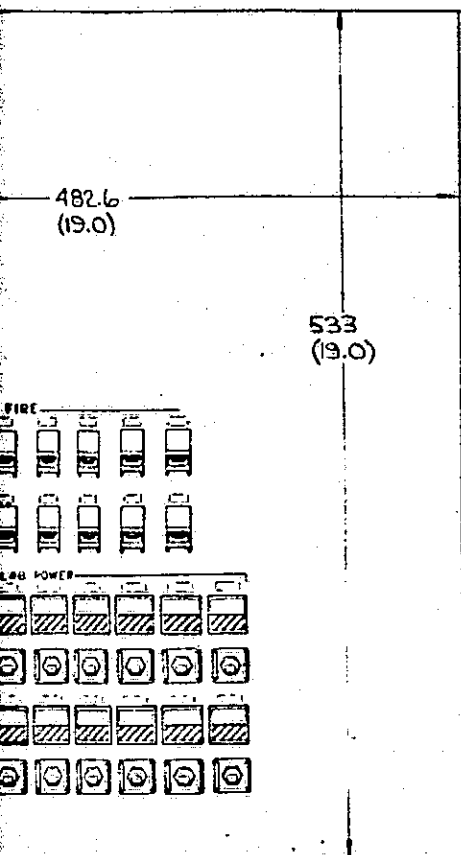
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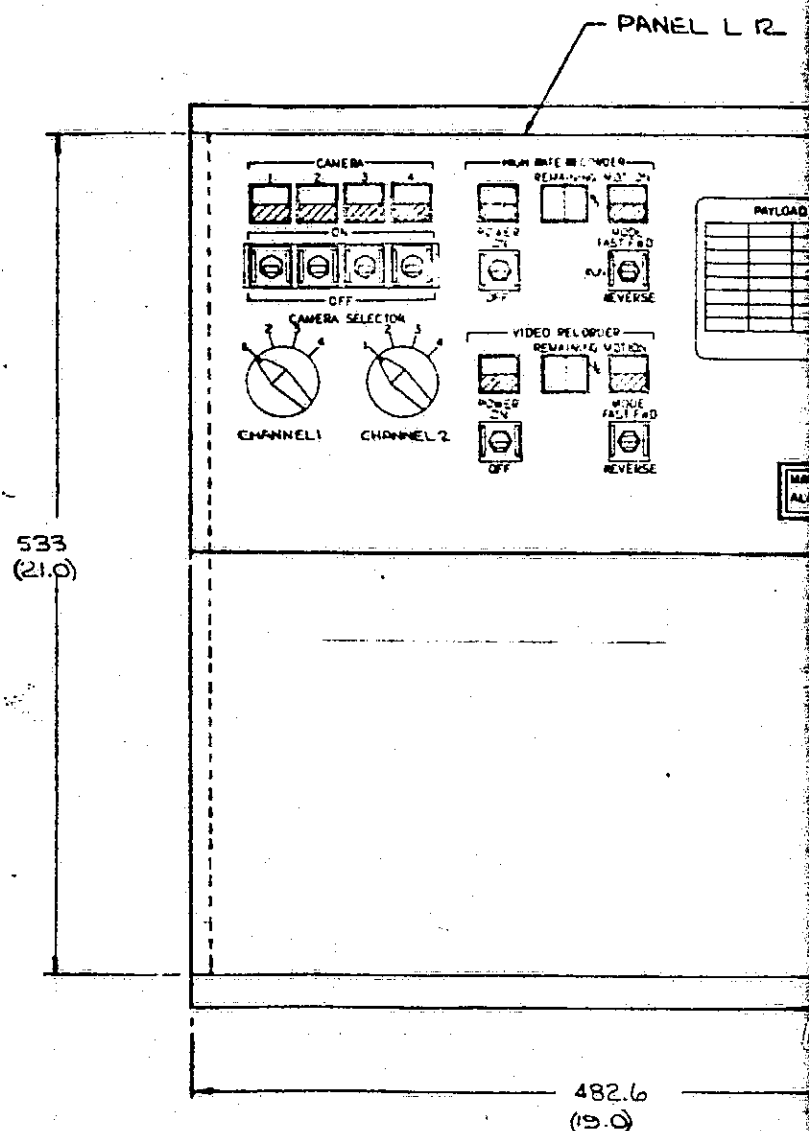
VIEW A TRUE VIEW ON MSS PANEL R 11
SCALE 1/2

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ON MSS PANEL R II

SCALE 1/2



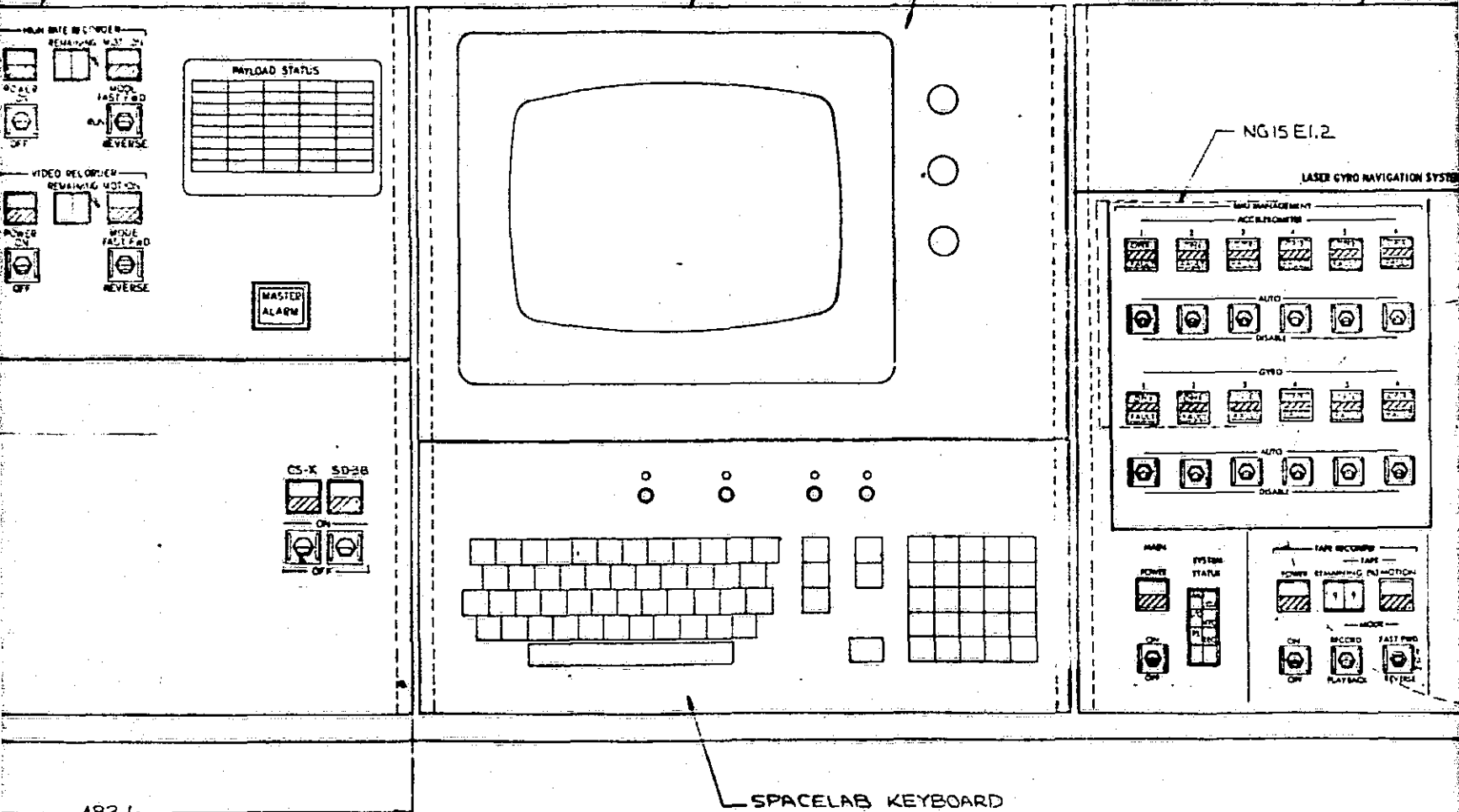
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FOLDOUT FRAME 3

PANEL L12

PANEL L11

SPACELAB DATA DISPLAY UNIT



VIEW B - TRUE VIEW ON
PAYLOAD SPECIALIST STATION
SCALE $\frac{1}{2}$

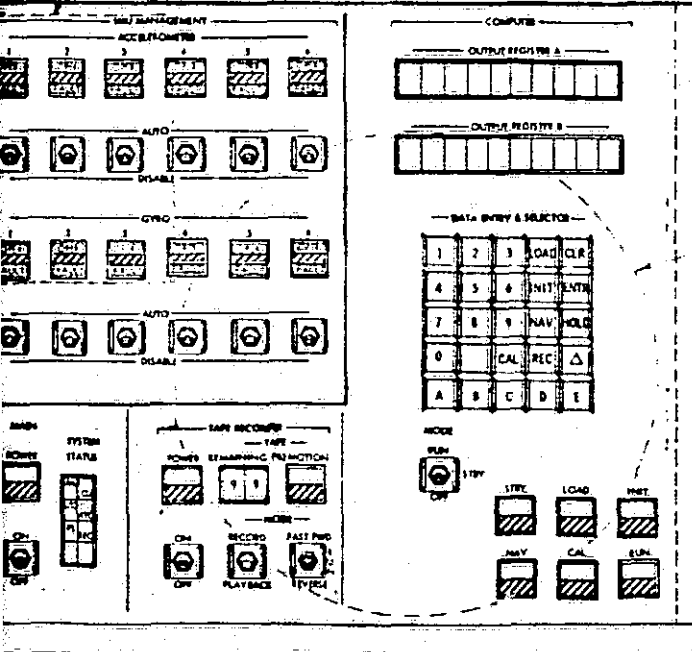
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A DISPLAY UNIT

PANEL L10

NG15 E1.2

LASER GYRO NAVIGATION SYSTEM



NG15 E1.6

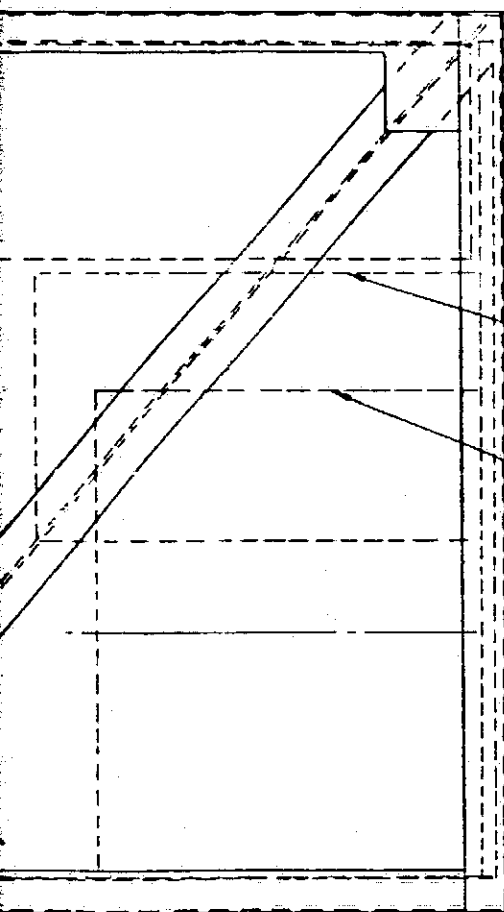
NG15 E1.1

INPUT OUTPUT CONTROLLER AND DISPLAY NG15 E1.6
DIGITAL TAPE RECORDER NG15 E1.6

INNER STRUCTURAL MODULE T
SUPPORT NG15 EQUIPMENT

FOLDOUT FRAME 4

CONTROLLER AND DISPLAY NG15 E1 3
DIGITAL TAPE RECORDER NG15 E1 6



COMPUTER NG15 E1 2

STRAPDOWN IMU NG15 E1 1

CONSOLE MODULE STRUCTURE

INNER STRUCTURAL MODULE TO
SUPPORT NG15 EQUIPMENT

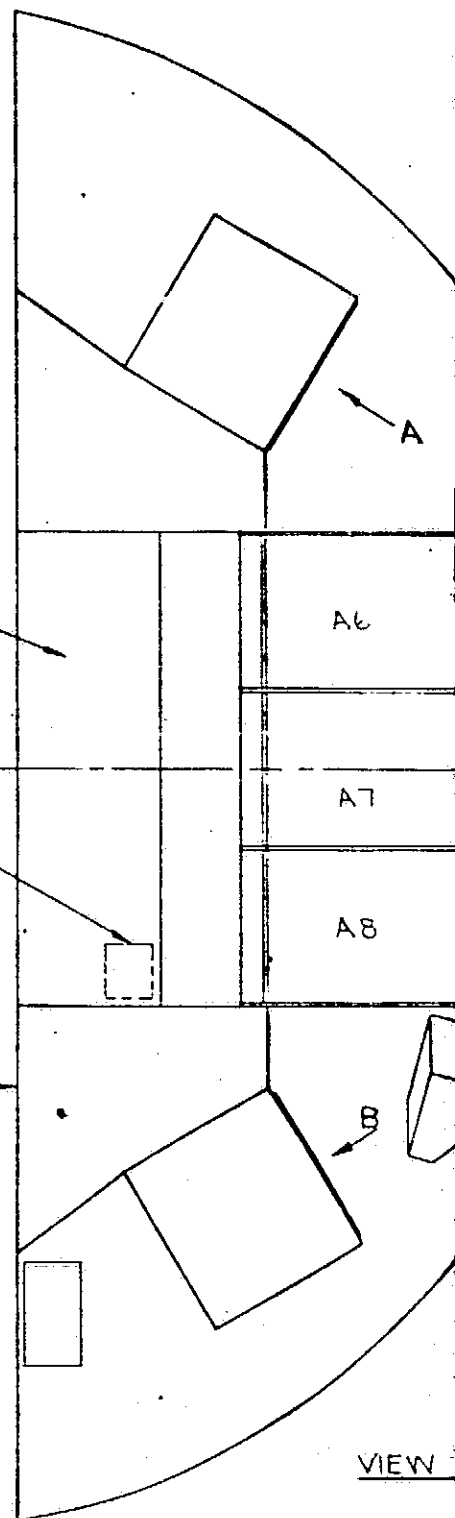
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STORAGE

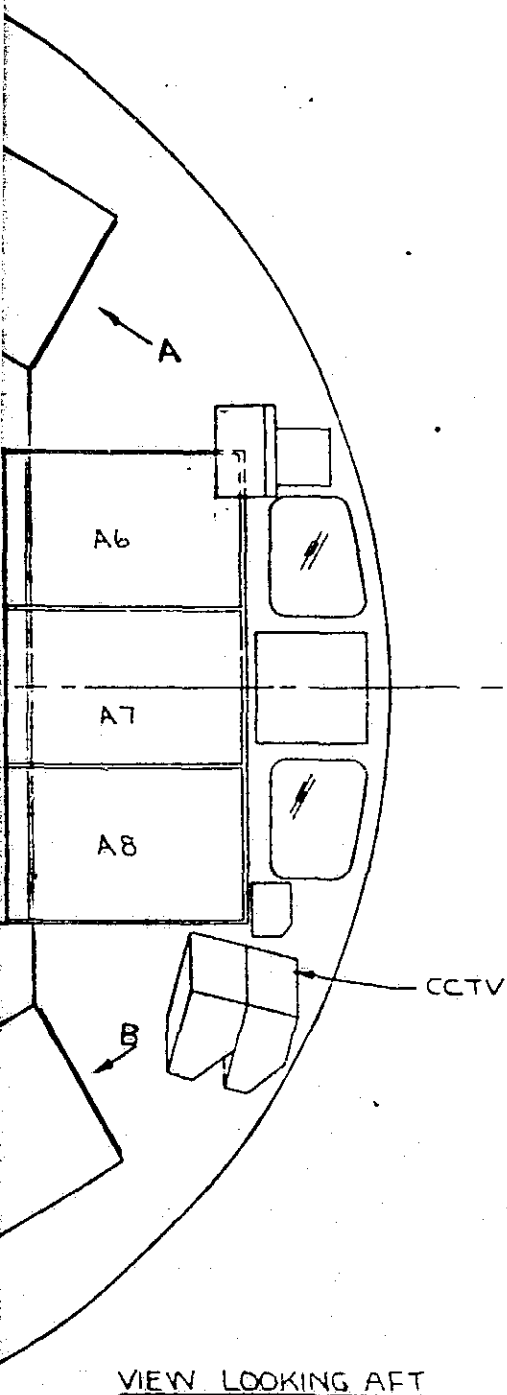
NG-15 TAPE STORAGE

Z. - 419.0

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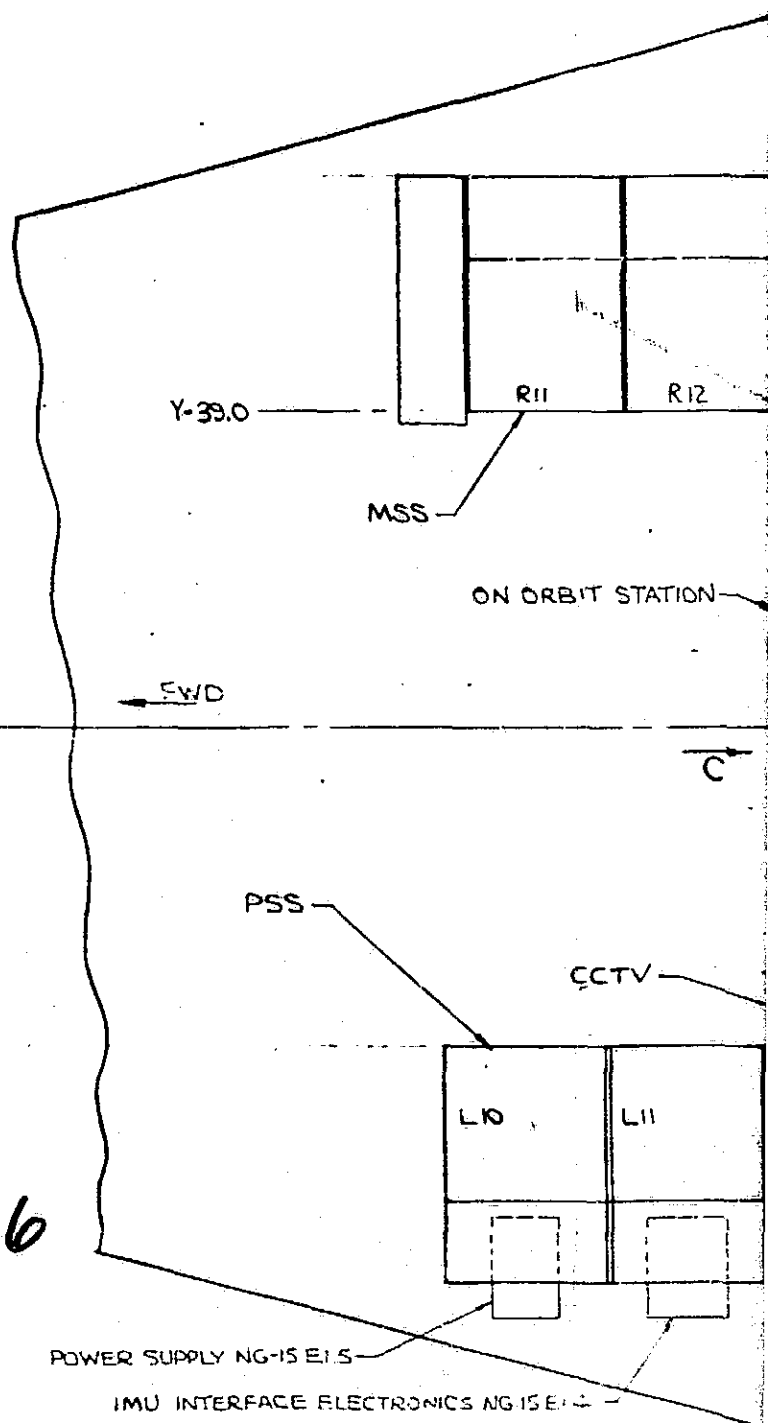


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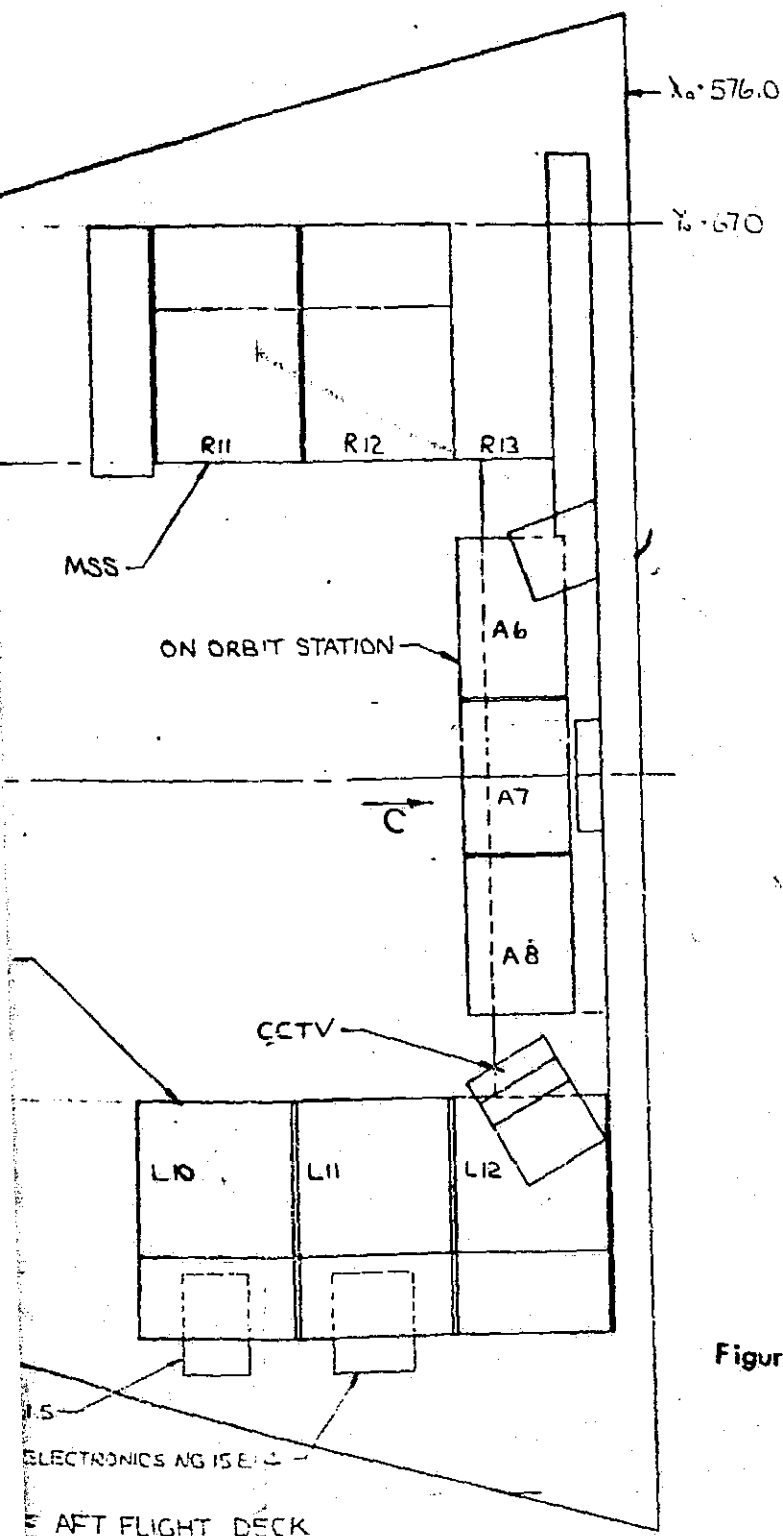


VIEW LOOKING AFT

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PLAN VIEW OF AFT FLIGHT DECK



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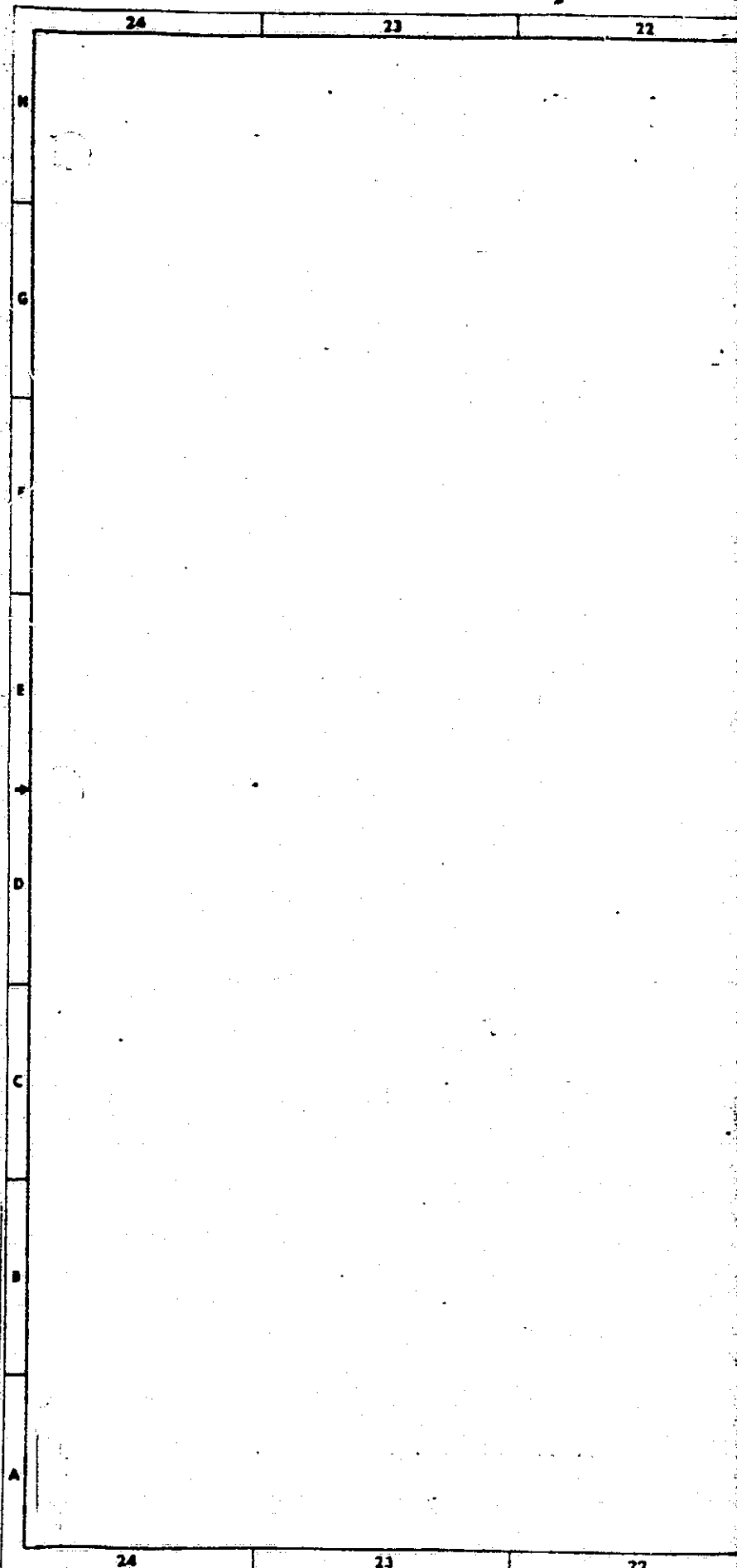
Figure 5-16. ATL D&C Installation Layout in the Aft Flight Deck

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BY	DATE	SPACE DIVISION	
BY	DATE	1400 GARDEN DRIVE, GARDEN CITY, CALIFORNIA	
AFT FLIGHT DECK DISPLAYS AND CONTROLS - PAYLOAD A ATL STUDY			2511-27

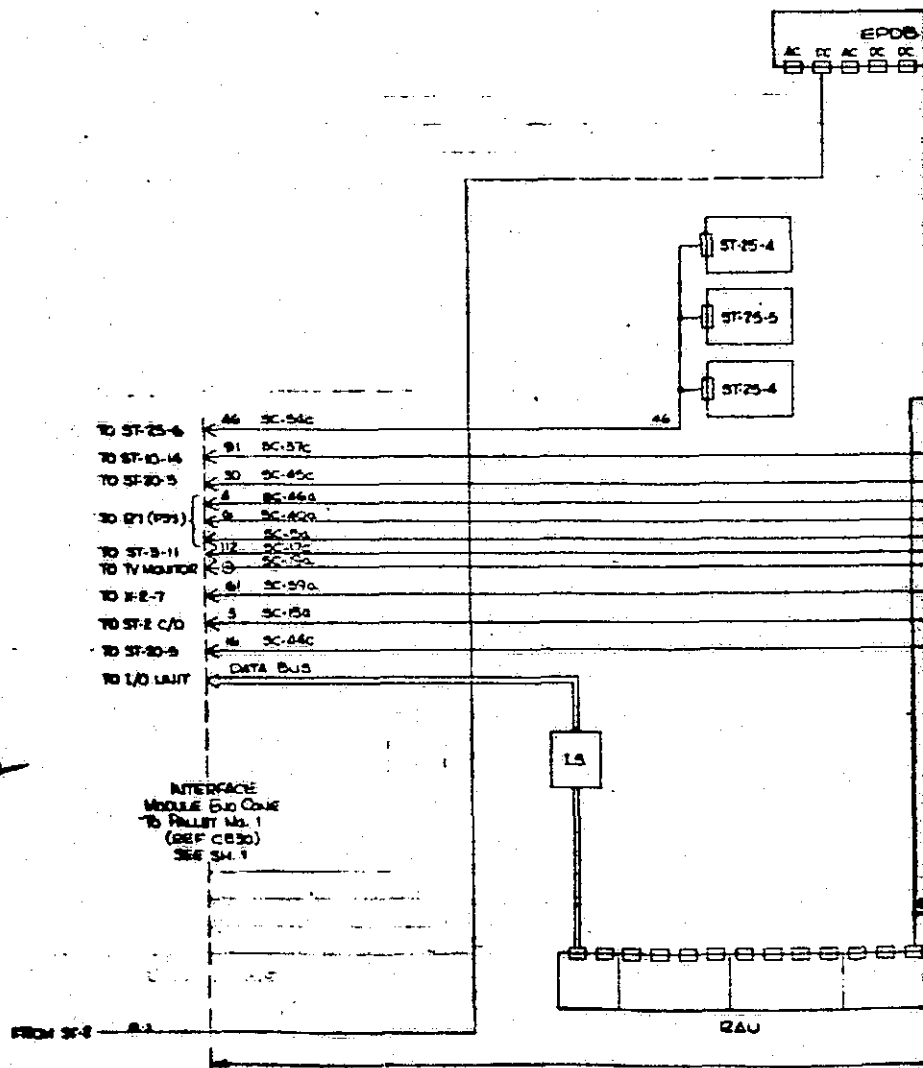
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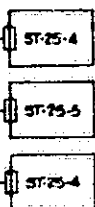
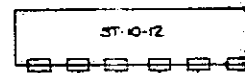
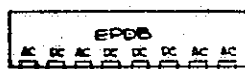


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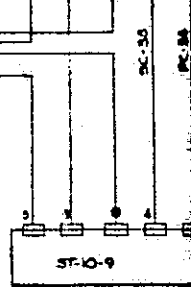
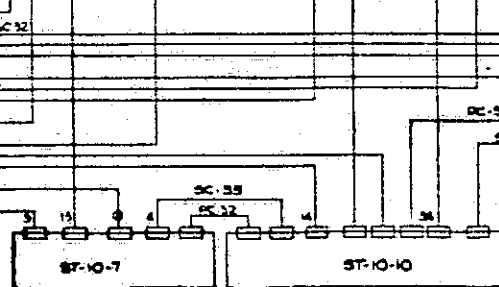
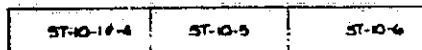
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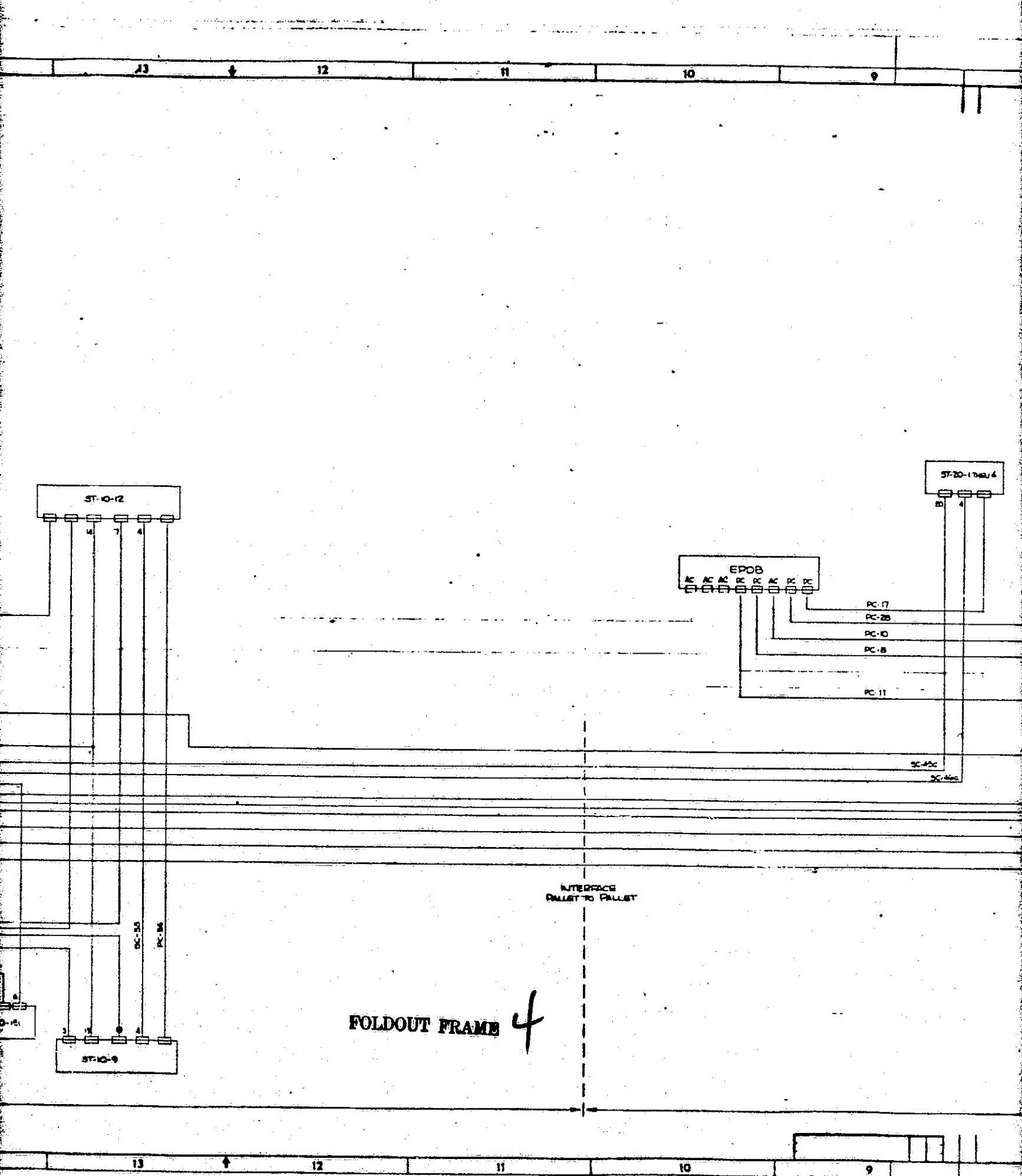
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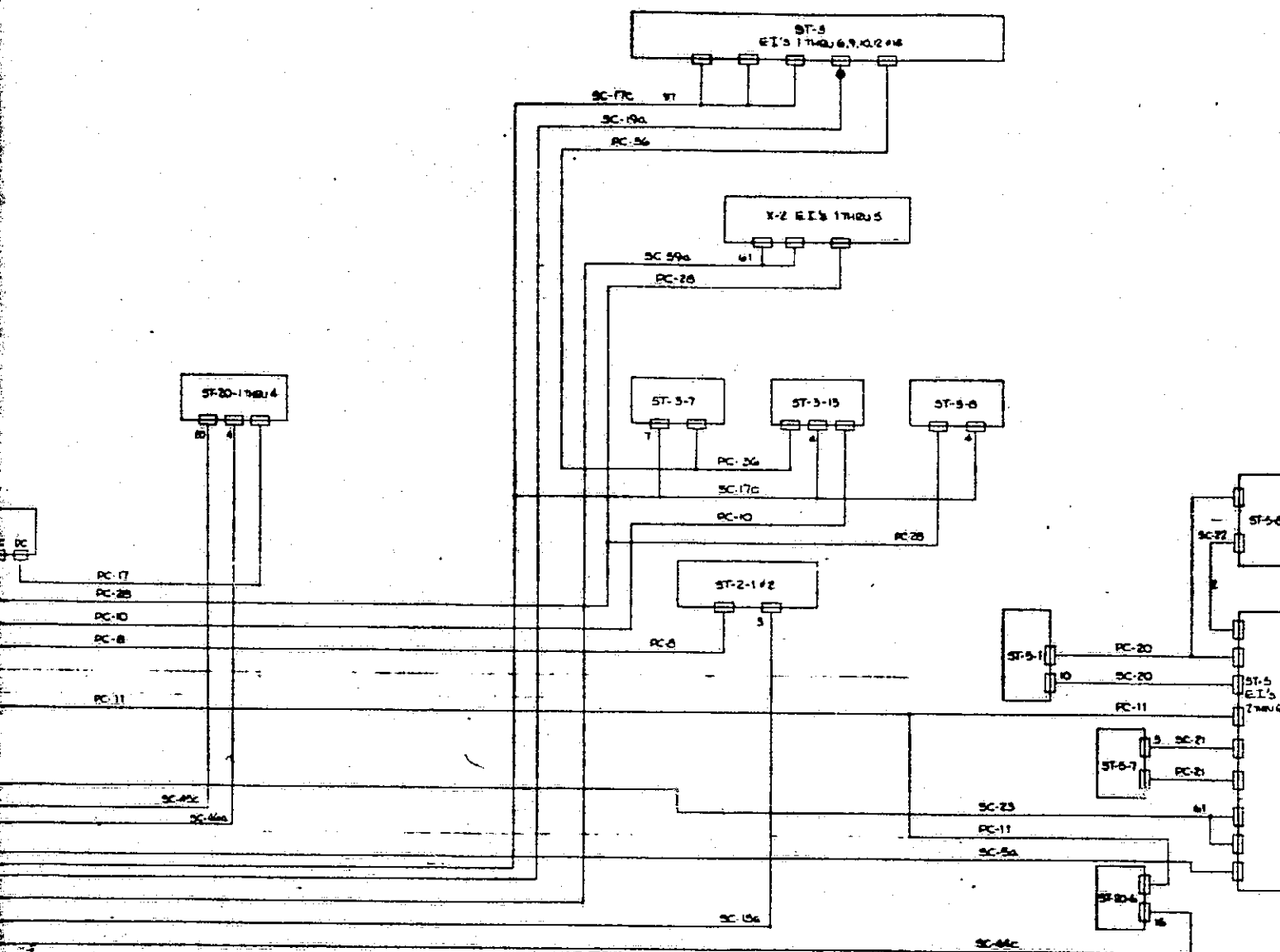
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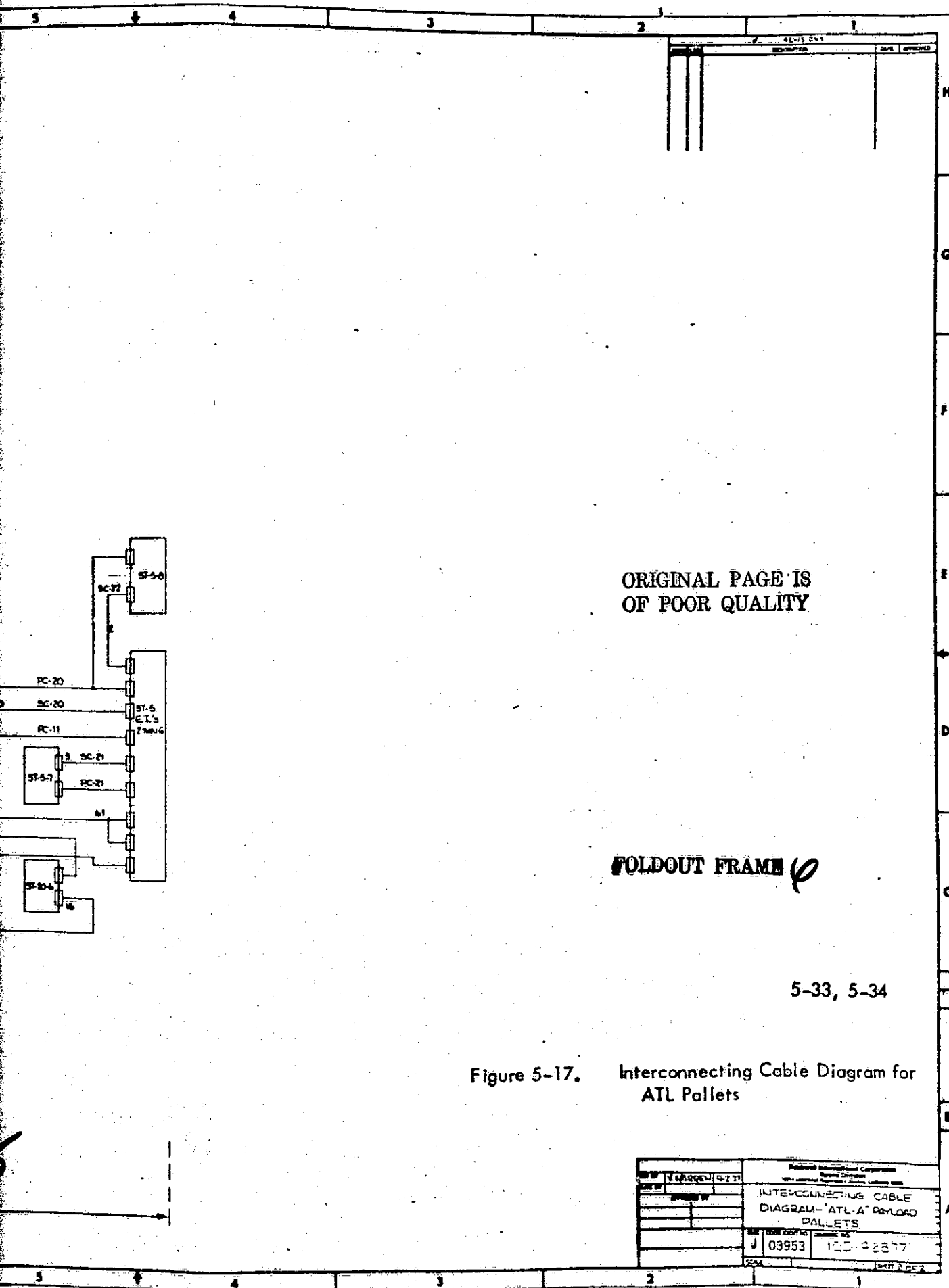




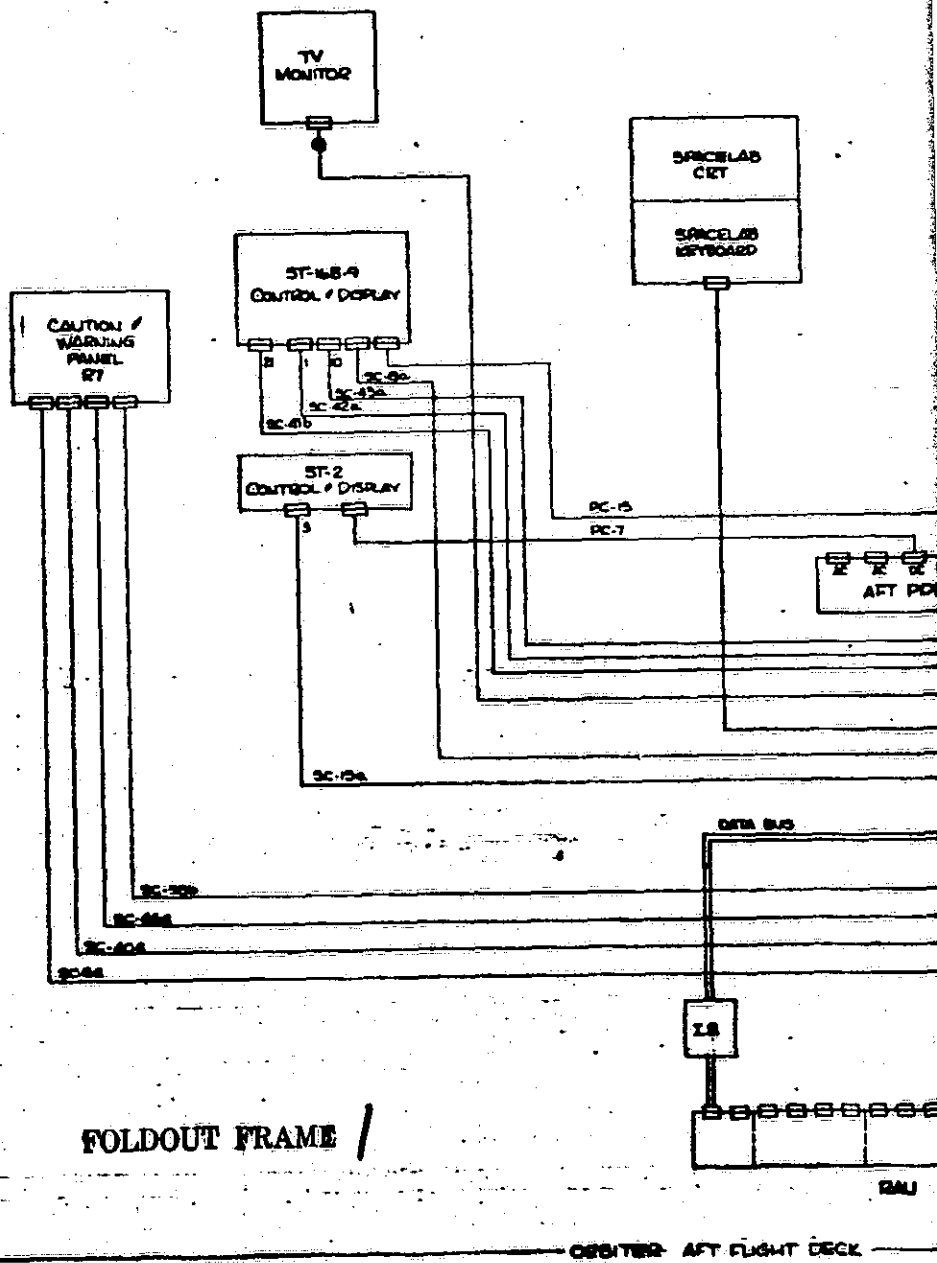
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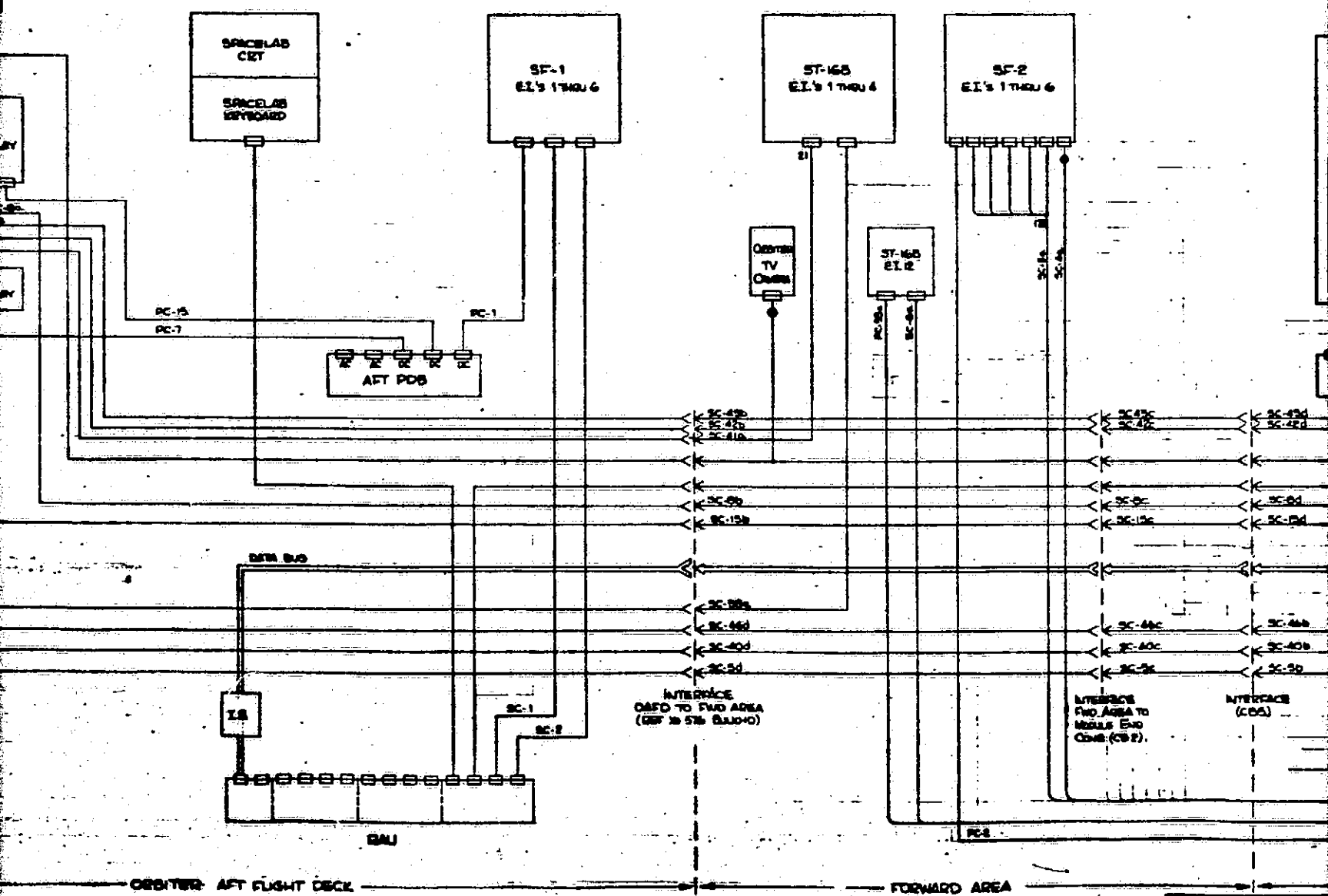
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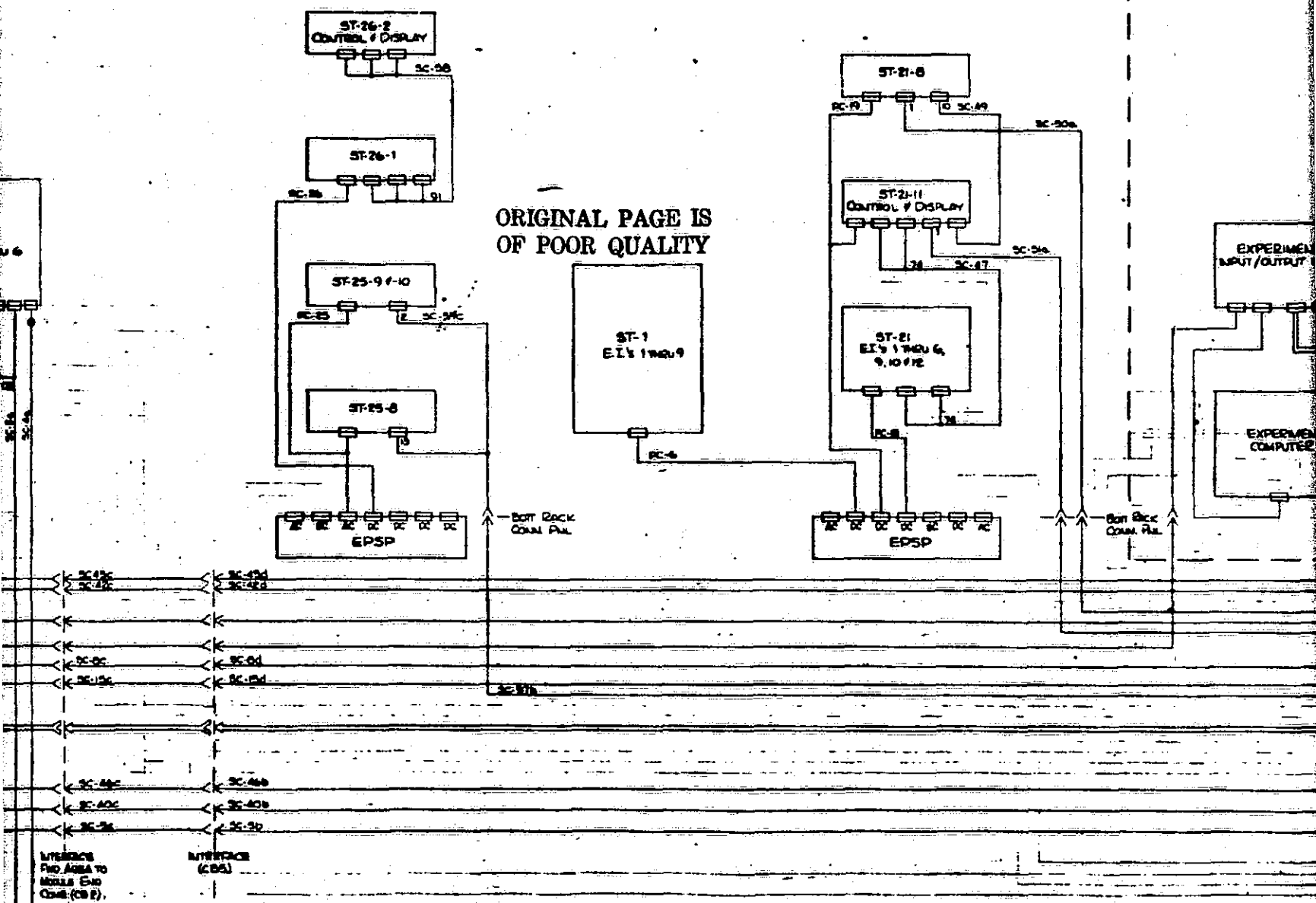
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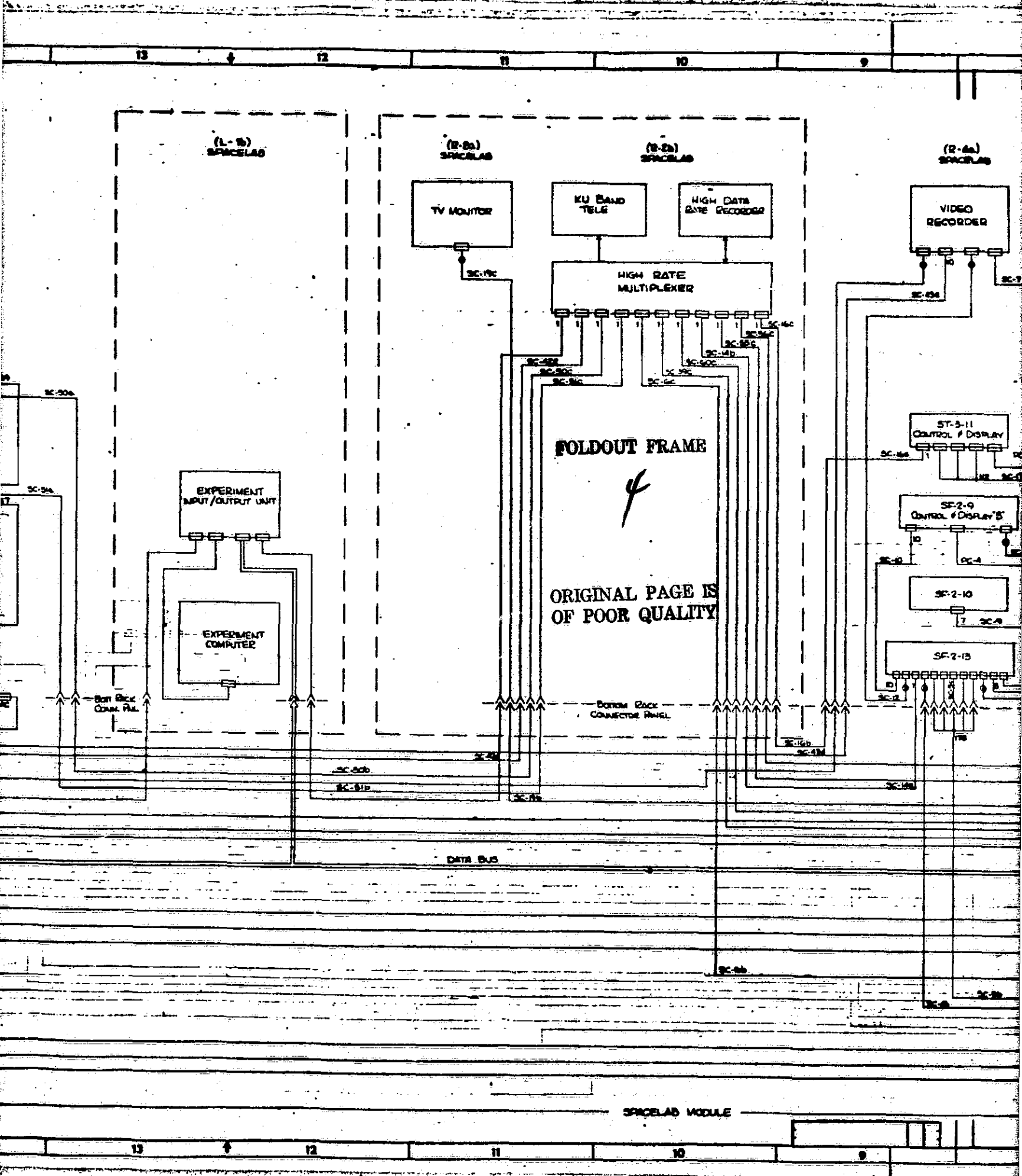
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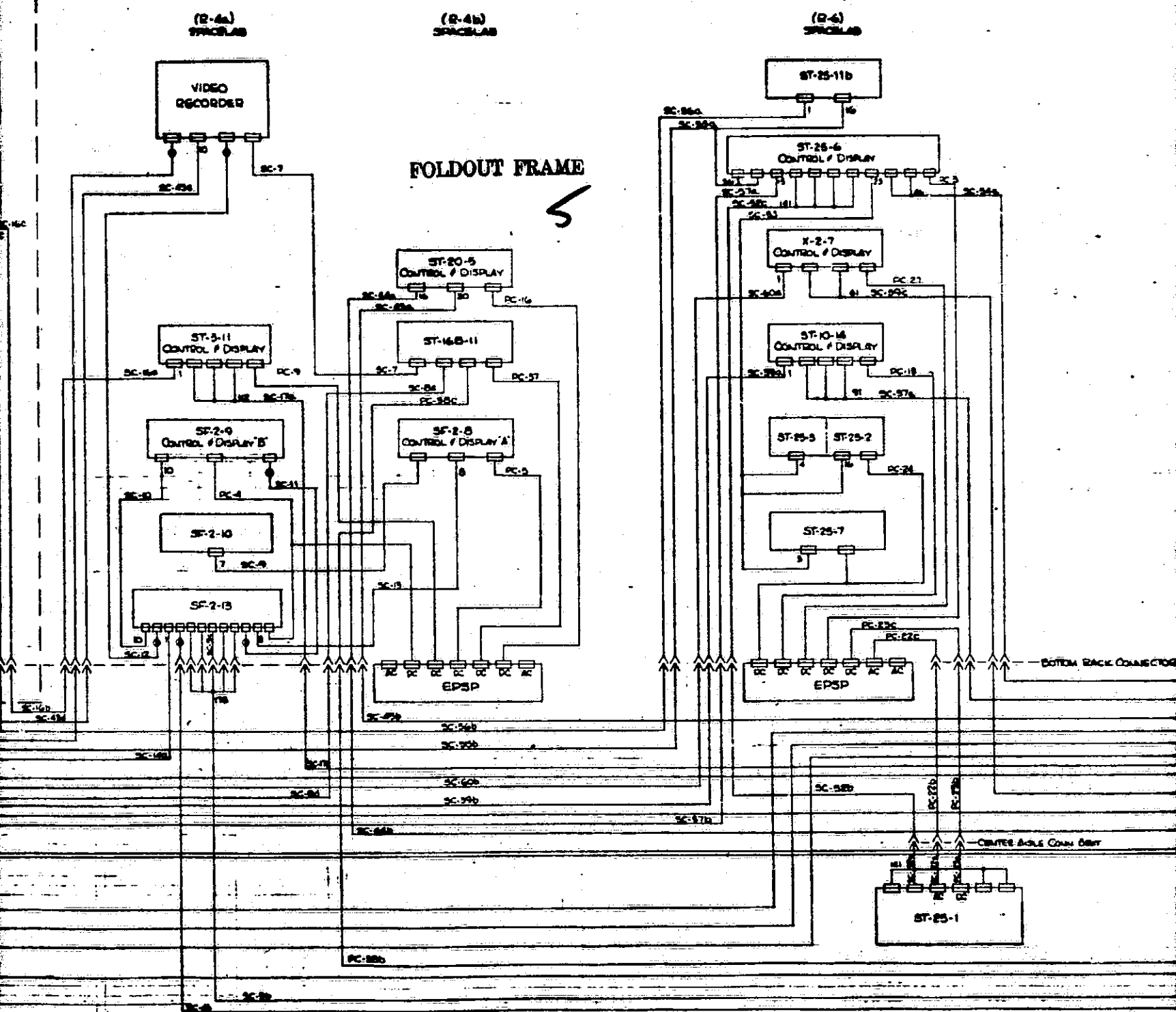
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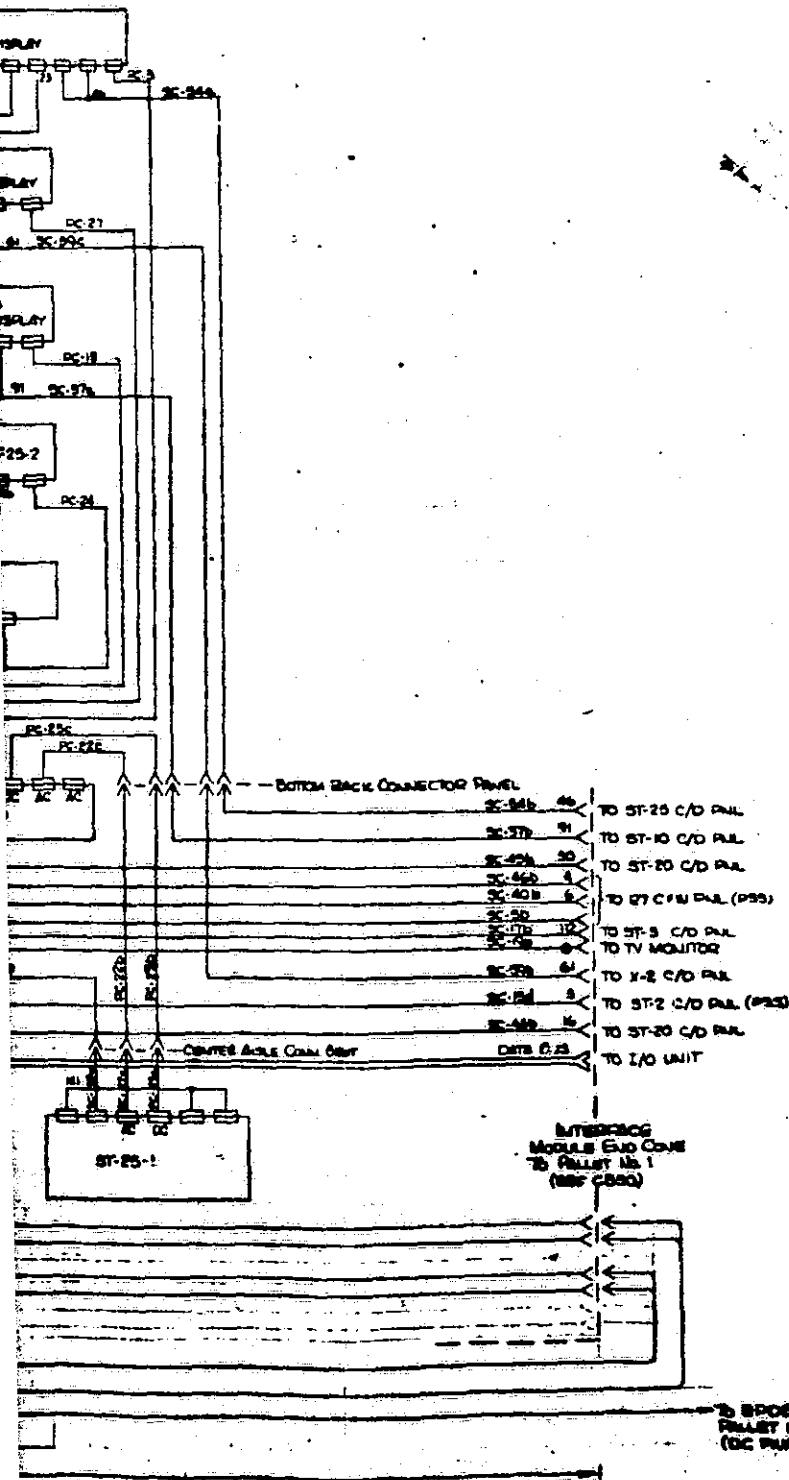


Figure 5-18. Interconnecting Cable Diagram for Module Mounted ATL Experiments

5-35, 5-36

INTERCONNECTING CABLE	
DIAGRAM - ATL-A PAYLOAD	
SPACE-45 MODULE	
J 03953	CD-92877
PART 1 OF 2	

SD 78-SR-0008-T



Table 5-3. ATL Payload Cabling Requirements

Experiment	Cable Identification	Between	And	Est. Length (Feet)
SF-1	PC-1 (DC)	E.I.'s 1 thru 6	OAFD Patch Panel	6
	SC-1	E.I.'s 1 thru 6	OAFD RAU	5
	SC-2	E.I.'s 1 thru 6	OAFD RAU	
SF-2	PC-2 (DC)	E.I.'s 1 thru 6	EPDB on Pallet #1	32
	PC-4 (DC)	E.I. 9 and E.I. 13	EPSP in S/L Rack R-4b	10
	PC-5 (DC)	E.I. 8	EPSP in S/L Rack R-4b	4
	SC-3a	E.I.'s 1 thru 6	CB30	28
	SC-3b	CB30	Batt Rack Conn Pnl (Rack R-4a)	13
	SC-3c	Batt Rack Conn Pnl (R-4a)	E.I. 13	4
	SC-4a(COAX)	E.I.'s 1 thru 6	CB30	28
	SC-4b	CB30	Batt Rack Conn Pnl (Rack R-4a)	13
	SC-4c	Batt Rack Conn Pnl (R-4a)	E.I. 13	4
	SC-10	E.I. 9	E.I. 13	8
	SC-11(COAX)	E.I. 9	E.I. 13	8
	SC-12(COAX)	E.I. 13	Video Rec'dr in S/L Rack R-4a	3
	SC-13	E.I. 13	E.I. 8	3
	SC-14a	E.I. 13	Batt Rack Conn Pnl (Rack R-4a)	7
	SC-14b	Batt Rack Conn Pnl (R-4a)	H.R.M.	
ST-1	PC-6 (DC)	E.I.'s 1 thru 9	EPSP in S/L Rack L-3a	7
	SC-9	E.I. 10	E.I. 8	2
ST-2	PC-7 (DC)	Control/Display Pnl	OAFD Patch Panel	6
	PC-8 (DC)	E.I.'s 1 and 2	EPDB on Pallet #2	4
	SC-15a	Control/Display Pnl	OAFD Patch Panel	4
	SC-15b	CB2	CB5	2
	SC-15c	CB5	CB30	6
ST-3	SC-15d	CB30	E.I.'s 1 and 2	15
	PC-9 (DC)	E.I. 11	EPSP in S/L Rack R-4b	4
	PC-10 (AC)	E.I. 13	EPDB on Pallet #2	7
	PC-36	E.I. 7 and E.I. 13	E.I.'s 1 thru 6, 9, 10, 12, 14	7
	PC-28	E.I. 8	EPDB on Pallet #2 and X-2, E.I.'s 1 thru 5	5
	SC-16a	E.I. 11	Batt Rack Conn Pnl (Rack R-4a)	6
	SC-16b	Batt Rack Conn Pnl (R-4a)	Batt Rack Conn Pnl (Rack R-2b)	
	SC-16c	Batt Rack Conn Pnl (R-2b)	H.R.M.	
	SC-17a	E.I. 11	Batt Rack Conn Pnl (Rack R-4a)	4
	SC-17b	Batt Rack Conn Pnl (R-4a)	CB30	9
	SC-17c	CB30	E.I.'s 1 thru 10, 12, 13 & 14	23



Table 5-3. ATL Payload Cabling Requirements (Cont.)

Experiment	Cable Identification	Between	And	Est. Length (Feet)
ST-3 (Cont)	SC-19a(COAX)	E.I.'s 1 thru 6, 9, 10, 12 & 14	CB30	23
	SC-19b	CB30	Batt Rack Conn Pnl (Rack R-2a)	9
	SC-19c	Batt Rack Conn Pnl (R-2a)	TV Monitor in S/L Rack R-2a	6
ST-5	PC-11	E.I. 2 thru 6 & ST-20-6	EPDB on Pallet #2	9
	PC-20	E.I. 2 thru 6	E.I.'s 1 and 8	13
	PC-21	E.I.'s 2 thru 6	E.I. 7	2
	SC-20	E.I. 1	E.I.'s 2 thru 6	6
	SC-21	E.I.'s 2 thru 6	E.I. 7	2
	SC-22	E.I.'s 2 thru 6	E.I. 8	6
	SC-23	E.I.'s 2 thru 6	RAU on Pallet #1	15
	SC-5a	E.I. 4	CB30	15
	SC-5b	CB30	CB5	6
	SC-5c	CB5	CB2	2
	SC-5d	OAFD Patch Panel	R7 (C&W Panel)	6
ST-10	PC-12 (AC)	E.I.'s 10, 11 & 12	EPDB on Pallet #1	5
	PC-13 (DC)	E.I. 14	EPSP in S/L Rack R-6	4
	PC-29 (DC)	E.I.'s 1 and 4	E.I. 10	15
	PC-30 (DC)	E.I. 5	E.I. 11	23
	PC-31 (DC)	E.I. 6	E.I. 12	23
	PC-32 (DC)	E.I. 7	E.I. 10	2
	PC-33 (DC)	E.I. 8	E.I. 11	2
	PC-34 (DC)	E.I. 9	E.I. 12	9
	PC-35 (DC)	E.I. 10	E.I. 15	7
	SC-24	E.I.'s 1 and 4	E.I. 7	15
	SC-25 (COAX)	E.I.'s 1 and 4	E.I. 7	15
	SC-26	E.I.'s 1 and 4	E.I. 10	15
	SC-27	E.I. 5	E.I. 8	23
	SC-28 (COAX)	E.I. 5	E.I. 8	23
	SC-29	E.I. 5	E.I. 11	23
	SC-30	E.I. 6	E.I. 9	9
	SC-31 (COAX)	E.I. 6	E.I. 9	9
	SC-32	E.I. 6	E.I. 12	23
	SC-33	E.I. 7	E.I. 10	2
	SC-34	E.I. 8	E.I. 11	2
	SC-35	E.I. 9	E.I. 12	9
	SC-36	E.I. 10	E.I. 15	7
	SC-37a	E.I. 14 (C/D Pnl)	Batt Rack Conn Pnl (Rack R-6)	7
	SC-37b	Batt Rack Conn Pnl (R-6)	CB30	7
	SC-37c	CB30	E.I.'s 7, 10, 9 & 8, 11, 12	15



Table 5-3. ATL Payload Cabling Requirements (Cont.)

Experiment	Cable Identification	Between	And	Est. Length (Feet)
ST-10 (Cont.)	SC-39a	E.I. 14	Batt Rack Conn Pnl (Rack R-6)	7
	SC-39b	Batt Rack Conn Pnl (R-6)	Batt Rack Conn Pnl (Rack R-2b)	
	SC-39c	Batt Rack Conn Pnl (R-2b)	H.R.M.	10
	SC-40a	E.I. 15	CB30	6
	SC-40b	CB30	CB5	2
	SC-40c	CB5	CB2	6
	SC-40d	OAFD Patch Panel	R7 (C&W Panel)	
ST-16B	PC-38a	E.I. 12	CB30	28
	PC-38b	CB30	Batt Rack Conn Pnl (Rack R-4b)	12
	PC-38c	Batt Rack Conn Pnl (R-4b)	E.I. 11	3
	PC-15 (DC)	E.I. 9	OAFD Patch Panel	6
	PC-37 (DC)	E.I. 11	EPSP in S/L Rack R-4b	3
	SC-6a	E.I. 12	CB30	28
	SC-6b	CB30	Batt Rack Conn Pnl (Rack R-2b)	15
	SC-6c	Batt Rack Conn Pnl (R-2b)	H.R.M.	5
	SC-7	E.I. 11	Video Rec'dr in S/L Rack R-4a	3
	SC-8a	E.I. 9	OAFD Patch Panel	4
	SC-8b	CB2	CB5	2
	SC-8c	CB5	Batt Rack Conn Pnl (Rack R-4b)	11
	SC-8d	Batt Rack Conn Pnl (R-4b)	E.I. 11	3
	SC-41a	OAFD Patch Panel	E.I. 9 (C/D Pnl)	4
	SC-42a	E.I. 9	OAFD Patch Panel	4
	SC-42b	CB2	CB5	2
	SC-42c	CB5	Batt Rack Conn Pnl (Rack R-2a)	7
	SC-42d	Batt Rack Conn Pnl (R-2a)	H.R.M.	5
	SC-43a	E.I. 9	OAFD Patch Panel	4
	SC-43b	CB2	CB5	2
	SC-43c	CB5	Batt Rack Conn Pnl (Rack R-4a)	11
	SC-43d	Batt Rack Conn Pnl (R-4a)	Video Rec'dr in S/L Rack R-4a	4
	SC-38c	OAFD Patch Panel	R7 (C&W Panel)	6
ST-20	PC-16 (DC)	E.I. 5 (C/D Pnl)	EPSP in S/L Rack R-4b	7
	PC-17 (DC)	E.I.'s 1 thru 4	EPDB on Pallet #2	6
	SC-44a	E.I. 5	Batt Rack Conn Pnl (Rack R-4b)	6
	SC-44b	Batt Rack Conn Pnl (R-4b)	CB30	10
	SC-44c	CB30	E.I. 6	20



Table 5-3. ATL Payload Cabling Requirements (Cont.)

Experiment	Cable Identification	between	And	Est. Length (Feet)
ST-20 (Cont.)	SC-45a	E.I. 5	Bott Rack Conn Pnl(Rack R-4b)	6
	SC-45b	Bott Rack Conn Pnl (R-4b)	CB30	10
	SC-45c	CB30	E.I.'s 1 thru 4	22
	SC-46a	E.I.'s 1 thru 4	CB30	22
	SC-46b	CB30	CB5	10
	SC-46c	CB5	CB2	3
	SC-46d	OAFD Patch Panel	R7 (C&W Panel)	6
ST-21	PC-18 (DC)	E.I.'s 1 thru 6, 9, 10 & 12	EPSP in S/L Rack L-3a	9
	PC-19 (DC)	E.I. 8 & E.I. 11 (C/D Pnl)	EPSP in S/L Rack L-3a	3
	SC-49	E.I. 8	E.I. 11	3
	SC-50a	E.I. 8	Bott Rack Conn Pnl(Rack L-3a)	3
	SC-50b	Bott Rack Conn Pnl (L-3a)	Bott Rack Conn Pnl(Rack R-2b)	10
	SC-50c	Bott Rack Conn Pnl (R-2b)	H.R.M.	6
	SC-47	E.I.'s 1 thru 6, 9, 10 & 12	E.I. 11	9
	SC-51a	E.I. 11	Bott Rack Conn Pnl(Rack L-3a)	1
	SC-51b	Bott Rack Conn Pnl (L-3a)	Bott Rack Conn Pnl(Rack R-2b)	10
	SC-51c	Bott Rack Conn Pnl (R-2b)	H.R.M.	6
ST-25	PC-3	E.I. 6 (C/D Pnl)	EPSP in S/L Rack R-6	7
	PC-22a (AC)	E.I. 1	Center Aisle Conn Brkt	5
	PC-22b	Center Aisle Conn Brkt	Bott Rack Conn Pnl(Rack R-6)	
	PC-22c	Bott Rack Conn Pnl (R-6)	EPSP in S/L Rack R-6	3
	PC-23a (DC)	E.I. 1	Center Aisle Conn Brkt	5
	PC-23b	Center Aisle Conn Brkt	Bott Rack Conn Pnl (Rack R-6)	
	PC-23c	Bott Rack Conn Pnl (R-6)	EPSP in S/L Rack R-6	3
	PC-24 (DC)	E.I. 2 and E.I. 7	EPSP in S/L Rack R-6	7
	PC-25 (AC)	E.I. 8 and E.I.'s 9 & 10	EPSP in S/L Rack L-5	3
	SC-52a	E.I. 1	Center Aisle Conn Brkt	5
	SC-52b	Center Aisle Conn Brkt	Bott Rack Conn Pnl(Rack R-6)	
	SC-52c	Bott Rack Conn Pnl (R-6)	E.I. 6	5
	SC-53	E.I.'s 2 & 3 and E.I. 7	E.I. 6	5
	SC-54a	E.I. 6	Bott Rack Conn Pnl (Rack R-6)	4
	SC-54b	Bott Rack Conn Pnl (R-6)	CB30	15
	SC-54c	CB30	E.I.'s 4 and 5	3
	SC-55a	E.I. 6 and E.I. 11b	Bott Rack Conn Pnl (Rack R-6)	5
	SC-55b	Bott Rack Conn Pnl (R-6)	Bott Rack Conn Pnl (Rack R-2b)	
	SC-55c	Bott Rack Conn Pnl (R-2b)	H.R.M.	5
	SC-56a	E.I. 11b	Bott Rack Conn Pnl(Rack R-6)	
	SC-56b	Bott Rack Conn Pnl (R-6)	Bott Rack Conn Pnl(Rack R-2b)	
	SC-56c	Bott Rack Conn Pnl (R-2b)	H.R.M.	



Table 5-3. ATL Payload Cabling Requirements (Cont.)

Experiment	Cable Identification	Between	And	Est. Length (Feet)
ST-25 (Cont.)	SC-57a	E.I. 6	Batt Rack Conn Pnl (Rack R-6)	5
	SC-57b	Batt Rack Conn Pnl (R-6)	Batt Rack Conn Pnl (Rack L-5)	8
	SC-57c	Batt Rack Conn Pnl (L-5)	E.I. 8 and E.I.'s 9 & 10	3
ST-26	PC-26 (DC)	E.I. 1	EPSP in S/L Rack L-5	4
	SC-58	E.I. 1	E.I. 2 (C/D Panel)	1
X-2	PC-27 (DC)	E.I. 7 (C/D Panel)	EPSP in S/L Rack R-6	3
	PC-28 (DC)	E.I.'s 1 thru 5	EPDB on Pallet #2	5
	SC-59a	E.I.'s 1 thru 5	CB30	23
	SC-59b	CB30	Batt Rack Conn Pnl (Rack R-6)	9
	SC-59c	Batt Rack Conn Pnl (R-6)	E.I. 7	3
	SC-60a	E.I. 7	Batt Rack Conn Pnl (Rack R-6)	10
	SC-60b	Batt Rack Conn Pnl (R-6)	Batt Rack Conn Pnl (Rack R-6)	
	SC-60c	Batt Rack Conn Pnl (R-6)	H.R.M.	



Table 5-4. ATL Payload Plumbing Requirements

Experiment	Fluid Transported	Purpose	Between	And
ST-3	LN ₂	Fill and Drain	EI-8	Pallet #2 Aft Connector Bracket
ST-5	Supercritical He	Flow to Radiometer for Cooling	EI-8	EI-1
		Vent	EI-8	Pallet #2, Aft Connector Bracket
ST-21	Waste Liquids	Vent	EI-6	Rack L-3 Vent Connector Panel
ST-25	Combustion Products	Vent	EI-1	Rack R-6 Vent Connector Panel
	O ₂	Supply to Combustion Chamber, EI-1	EI-4	Pallet #1 Forward Connector Bracket
	N ₂	Supply to Combustion Chamber, EI-1	EI-4	Pallet #1, Forward Connector Bracket
	CH ₄	Supply to Combustion Chamber, EI-1	EI-5	Pallet #1, Forward Connector Bracket



APPENDIX - VOLUME I

APPENDIX I-A

SPACELAB EQUIPMENT

The following is a brief description of the Spacelab equipment used in this study to aid the reader in understanding the relationships of these items. The reference source data is found in the "Spacelab-Payload Accommodation Handbook, SLP/2104" as prepared by the European Space Agency (ESA) and the NASA, and should be referred to for a detailed description of the total Spacelab system.

Table A-1 identifies the major unique Spacelab equipment included in this study.

Table A-1. Summary of Spacelab Equipment Studied

Payload	Spacelab Elements
Space Processing	Single Pallet
Combined Astronomy	Igloo, 3 single pallets, 1-2 pallet train
Life Science	Long Module
Advance Technology Laboratory	Short Module, 2 single pallets

GENERAL SPACELAB SYSTEM DESCRIPTION

Spacelab consists of two basic elements - a pressurized module and an unpressurized pallet - which can be used separately or in combination.

The modular design of the module (up to 2 segments) and the pallet (up to 5 segments) allows for a large variety of flight configurations.

These flight configurations can be grouped into three configuration types:

- module only
- module plus pallet
- pallet only



The module provides a controlled pressurized environment for the users and their equipment, and supplies basic services such as power, heat rejection and data management, together with certain basic support equipment such as standard racks, airlock, etc. which may be used as required. The pallet is an unpressurized platform to which instruments such as telescopes and antennas may be mounted which require direct exposure to space. The pallet provides basic services, such as power distribution, heat rejection and data acquisition and commands.

Spacelab is carried to and from orbit by the Space Shuttle. It remains attached to the Orbiter of the Space Shuttle throughout the flight.

In general, the Spacelab module consists of either a single cylindrical segment (core segment) or two segments (core plus experiment segment). The pallet only configuration may contain up to five pallet segments.

The Spacelab module can also be combined with pallet segments. Up to three pallet segments can be accommodated with a short module (core segment only) and up to two pallet segments can be combined with a long module (core and experiment segment). The module diameter is slightly over 4 meters and each cylindrical segment is approximately 2.7 meters long. The pallet segments are approximately 3 meters long and 4 meters wide.

The module itself is formed of a cylindrical pressure shell and cone-shaped end closures (end cones). It is covered with high-performance insulation. The module is structurally attached to the Orbiter by attach fittings located on the main ring frames of the module cylindrical segments. The forward located module segment (core segment) contains subsystem equipment and crew work space, but also leaves about 60 percent of the rack volume for experiment installation. The experiment segment is dedicated entirely to experiment installation and operations.

The Spacelab module must be located at the very forward end of the Orbiter cargo bay for center of gravity limitations. A tunnel is provided for crew and equipment transfer between the Orbiter and the Spacelab module.

The U-shaped pallet segments are covered with aluminum honeycomb panels. They are integral parts of the pallet structure, but can also be used for mounting of light weight payload equipment. A series of hardpoints attached to the main structure of a pallet segment is provided for mounting of heavy payload equipment. The pallet segments are mounted to the Orbiter with a set of attach fittings. Up to three pallet segments may be structurally linked together to form a pallet train and attached to the Orbiter by a single set of attach fittings. Up to five pallet segments may be flown on a single mission.

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Space Division

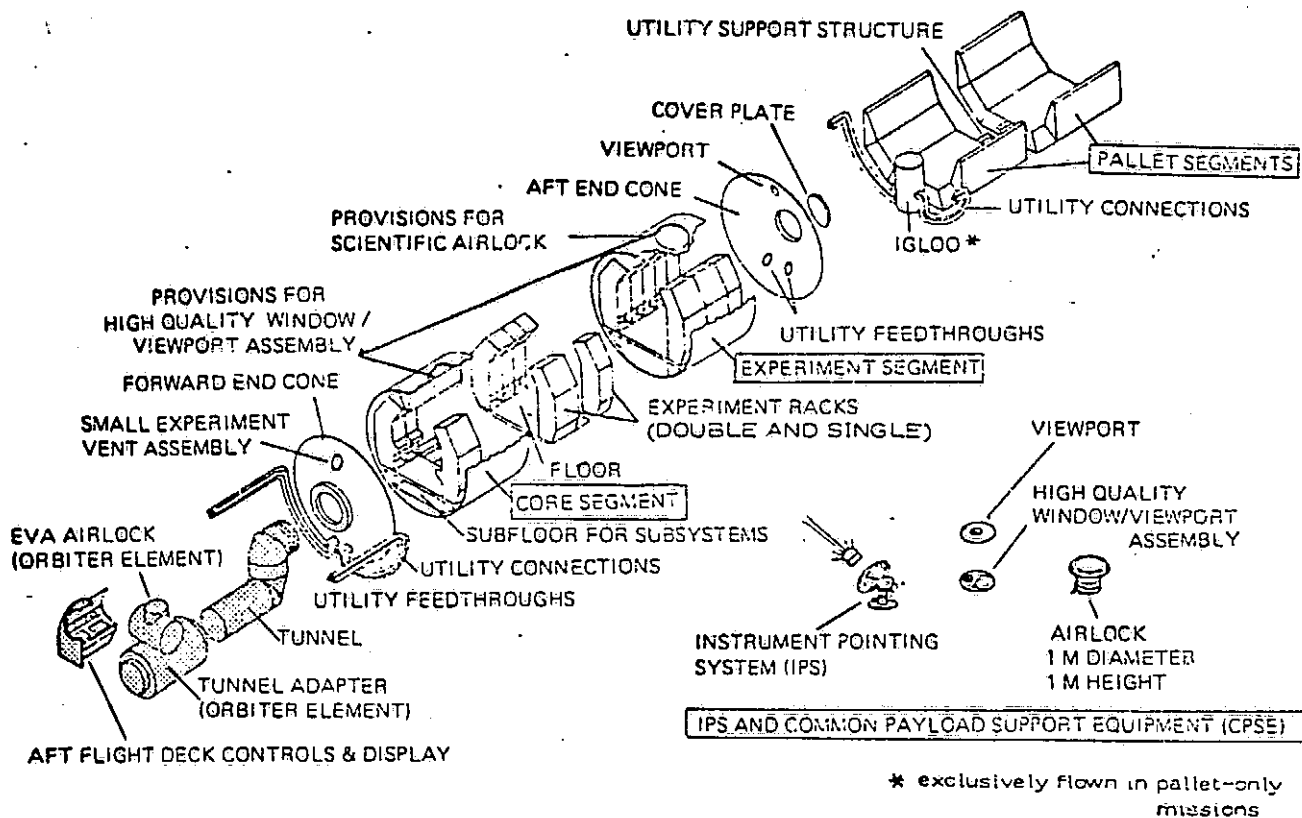


Figure A-1. Major Spacelab Flight Elements

Figure A-1 shows the major Spacelab flight elements. The EVA airlock and the tunnel adapter are part of the Shuttle program. The tunnel and the utility connections, Orbiter to module and Orbiter to Igloo, are part of the US Spacelab program. All other elements are part of the European Spacelab program.

The interior design of the module is modular and provides flexibility to the user. Racks are arranged in single and double rack assemblies for mounting of equipment. The floor is segmented. The most forward floor segment in the core segment provides support for the subsystem double rack assembly on each side. Other segments build up the floor for support of experiment rack for both the short and long module.

The core segment can accommodate one single and one double rack assembly for experiments while the experiment segment can accommodate one single and two double rack assemblies for experiments, on each side. The sequence of single and double racks must be as indicated in Figure A-1. The racks are attached independently from each other to the floor and overhead structure so that as many as necessary may be installed for a given mission. If some racks are not required, other special experiment equipment may be attached in their place.

The subsystem racks are also detachable but will normally remain installed in the core segment between flights. In operational use, the experiment racks and floors will normally be pre-integrated and checked out as a complete assembly. This assembly will then be rolled into the module shell. The necessary interface connections will then be made with the primary structure and the subsystems in the core segment.

In module only and module plus pallet configurations, Spacelab subsystems are mounted in the subsystem racks and on the subfloor as shown in Figure A-1. In these configurations the module can accommodate crew members for operation of subsystems and experiments. Signal, power and other utility lines to and from the Orbiter are routed from the forward end cone. In module plus pallet configurations, lines between module and pallet are routed via a utility support structure. For pallet configurations an "Igloo", a pressurized cylinder attached to a pallet, is provided for installation of certain subsystem hardware which is needed for pallet-only configurations. In pallet-only configuration, operations of subsystems and experiments will be performed from the Orbiter aft flight deck or from the ground. Signal and other utility lines to and from the Orbiter are routed from the Igloo. Spaced pallet segments are connected via a utility support structure.

Spacelab equipment in the aft flight deck (AFD) of the Orbiter permits the control of Spacelab subsystems and experiments, and permits the display of data. This aft flight deck equipment is independent of the Spacelab configurations flown. In the aft flight deck, there are also limited space and resources available for payload use.

The Spacelab flight hardware is divided into the following subsystems: Structure, environment control, electrical power and distribution, command and data management, and common payload support equipment.

The structure subsystem comprises essentially the mechanical parts of the module and pallet. Its prime function is to provide the required load carrying capability during ground and flight phases.

The environment control subsystem (ECS) comprises elements for environmental control, life support, and passive and active thermal control. The ECS includes a valve in the forward bulkhead by which experiment chambers, etc. inside the module can be connected with the outside vacuum. This facility is referred to as the small experiment vent assembly.

The electrical power and distribution subsystem (EPDS) conditions the basic electric power derived from the Orbiter fuel cells and distributes it to Spacelab subsystems and to Spacelab payloads via standard interfaces.

The command and data management subsystem (CDMS) provides support functions, such as data acquisition, command, formatting display and recording. The CDMS includes three identical computers: one dedicated to Spacelab payloads (with dedicated data bus), one dedicated to subsystems (with a dedicated subsystem data bus), both with standard interface units (RAU's) and one back-up computer for either of the two dedicated computers.

For high rate experiment data acquisition, a multiplexer is provided together with a re-recorder to bridge mission phases without data downlink. The CDMS subsystem is largely independent from the Orbiter. Communication with ground facilities, either via the Tracking and Data Relay Satellite System (TDRSS) or, as a back up, directly to a Space-flight Tracking and Data Network (STDN) station is provided through the Orbiter's communication system. System activation and monitoring (SAM) of Spacelab is performed through dedicated hardware and CDMS.

Common payload support equipment (CPSE) consists of an airlock, a top cover plate with a viewport and top cover plate with a high quality window and viewport.

The Spacelab program provides also software for operation of Spacelab on orbit and check-out of Spacelab on the ground. Furthermore, the program includes mechanical and electrical ground support equipment for integration and checkout of Spacelab.

Coarse pointing of Spacelab payloads is provided by the Orbiter. A Spacelab-supplied instrument pointing subsystem (IPS) permits high precision pointing of Spacelab payloads.

The following figures present the basic configurations of the long module, a general layout of a long module, the single and double racks available for experiments and a typical pallet-only configuration.

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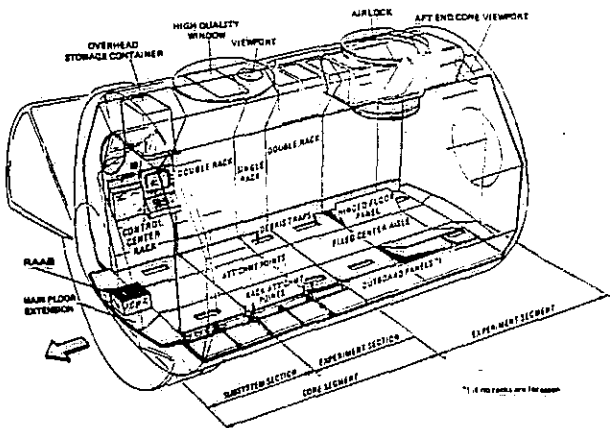


Figure A-2. General Overview - Long Module

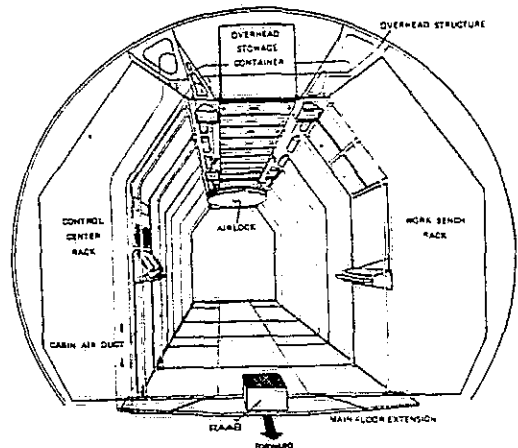


Figure A-3. General Layout - Long Module

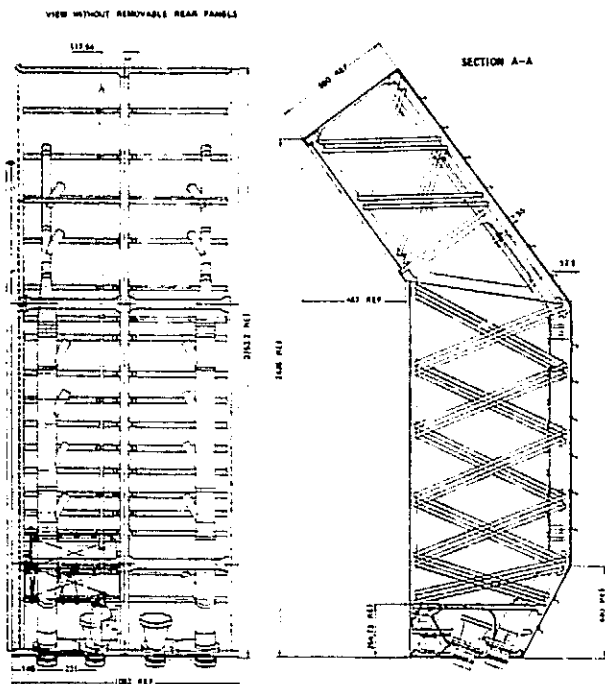


Figure A-4. Experiment Double Rack 3
(same for Rack 8 and 9)

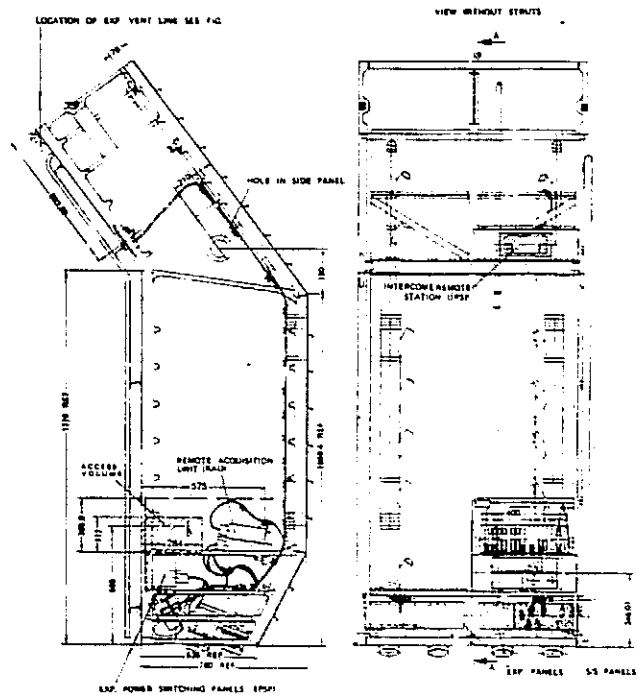


Figure A-5. Experiment Double Rack 7
(same for Rack 10)

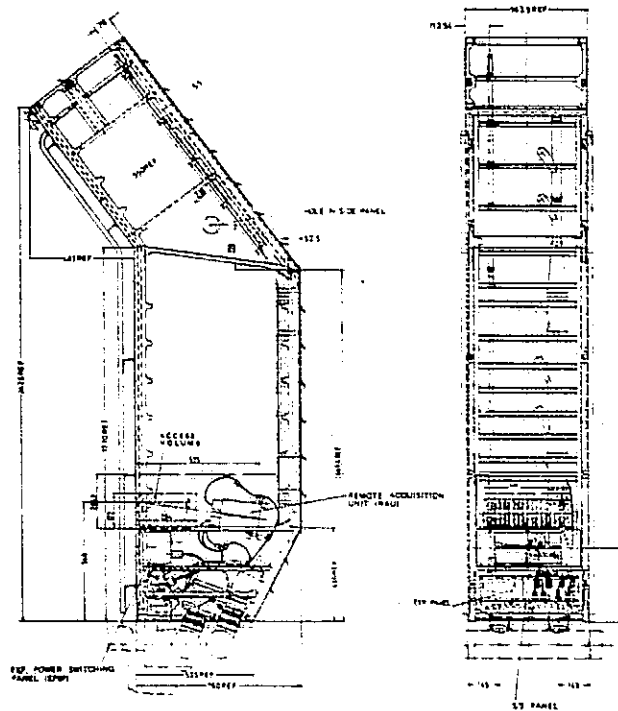


Figure A-6. Experiment Single Rack 5
(same for Rack 6, 11 and 12)



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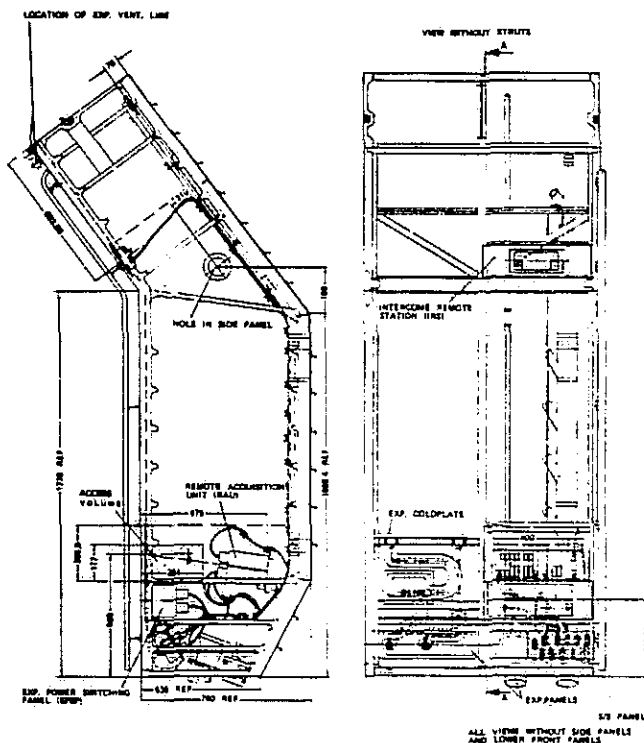


Figure A-7. Experiment Double Rack 4

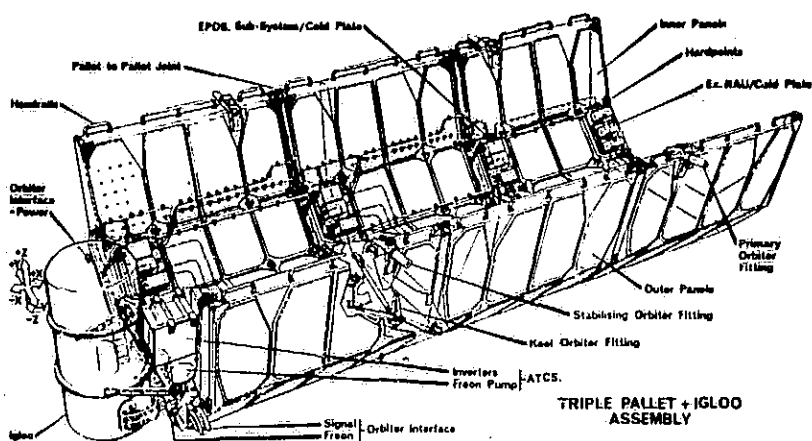


Figure A-8. General Pallet Configuration - Partial

APPENDIX I-B

DEFINITIONS OF PAYLOAD INTEGRATION LEVELS

The ground operations concept defines the general boundaries and constraints within which the payload integration approach has to be developed.

Typically, these constraints which are important to the development of a payload integration concept are:

- Individual payloads (single or groups of experiments) are assumed to be qualification/acceptance tested prior to meeting Spacelab flight hardware in the ground processing flow.
- Once the Spacelab ground processing flow is joined, the emphasis is placed on physical integration of the individual payloads into a total Spacelab payload and then into a complete Spacelab flight configuration. In general, payload testing is restricted to interface verification (experiment to experiment and payload to Spacelab subsystems) and an overall Spacelab mission simulation.
- The only payload dedicated operations currently planned in the baseline ground processing flow are essential calibration/re-calibration and servicing activities.

The complete payload integration process forms part of the Spacelab off-line and on-line flows as well as the Shuttle turnaround flow. The interaction between these flows is so arranged that there is a maximum decoupling between them, thus enabling each flow to "turnaround" in a timeframe which supports the overall STS objective of maximum hardware utilization.

The ground operational processing of Spacelab and Spacelab payloads is based on four levels of integration, the definition and scope of which are as follows:

Level IV Integration

Integration and checkout of experiment equipment with individual experiment mounting elements (e.g. racks and pallet segments).

Level IV integration is the lowest level of payload integration defined which involves basic SL hardware, and may be performed at sites remote from the launch site(s) within or outside the U.S.A.

Because Level IV integration involves Spacelab flight hardware the environment of the Level IV integration site has to satisfy the cleanliness requirements for at least standard class 100 K according to Federal Standard 209B, April 24, 1974, Clean Room and Work Station Requirements for Controlled Environment.

The scope of activities which may be performed at Level IV is primarily dependent upon:

- The type and complexity of the experiments involved
- The SL accommodations required by the experiments, i.e. the type, number and mix of Spacelab experiment mounting elements required (racks, pallets, etc.)
- The test facilities and equipment available at the Level IV site and provided by either the experimenter and/or the payload integrator.

The final level of hardware integration achieved at Level IV is somewhat dependent on the location of the particular sites in so far as the Level IV integrated hardware must subsequently be transported to the primary launch site (KSC) by one of the assigned SL transportation modes.

Current NASA planning is to pre-configure individual experiment racks and/or pallets with appropriate SL subsystem interfacing hardware (RAU's, power distribution boxes/panels, cold plates, etc.) at the primary launch site (KSC) prior to shipping these to the Level IV integration sites. This preconfiguring will be consistent with the Level IV activities planned for the particular experiments to be integrated.

Preconfigured experiment racks and/or pallets will be shipped to the Level IV integration sites with the MGSE required for handling and subsequent transportation back to the primary launch site.

Current NASA planning calls for the Level IV integrator and/or experimenters to provide all test equipment/GSE to functionally test/validate the experiments after installation and to validate hardware/software interfaces with the subsystem interfacing hardware.

Level III Integration

Combination, integration and checkout of all experiment mounting elements (e.g. racks, rack sets and pallet segments) with experiment equipment already installed.

Level III integration will normally be performed in the O&C building at the primary launch site (KSC) on receipt of the Level IV integrated individual experiment racks and/or pallets.

The scope of Level III activities which may be performed in the O&C building is to be restricted to assembly of already integrated experiment racks and/or pallets into rack/floor sets and pallet trains followed by mechanical integration of these with the already checked out basic SL into a complete Spacelab flight configuration.

Functional Level III testing of the integrated Spacelab payload in the O&C building is not currently planned prior to the integration of this with the basic Spacelab on board subsystems.

The possibility of performing "off line" Level III testing either at the launch site or elsewhere is dependent on the particular integrated payload configuration, and the facilities/GSE made available by the payload integrator to perform the required integration activities.

Level II Integration

Integration and checkout of the combined experiment equipment and experiment mounting elements (e.g. racks, rack sets and pallet segments) with the flight subsystem support elements (i.e. core segment, igloo) and experiment segments when applicable.

Level II integration will normally be performed in the O&C building at the primary launch site (KSC) following the mechanical integration of the Spacelab payload and basic Spacelab into a Spacelab flight configuration.

The scope of Level II activities as currently planned is primarily concerned with functional verification of Spacelab payload hardware and software interfaces to the on-board subsystems. An abbreviated mission simulation will also be run to functionally verify the completely integrated Spacelab system.

During Level II testing Spacelab/Orbiter functional interfaces will be simulated to allow limited "end to end" testing prior to Spacelab installation in the Orbiter.

Level I Integration

Integration and checkout of the Spacelab and its' payloads with the Shuttle Orbiter, including the necessary pre-installation testing with simulated interfaces.

Level I integration for KSC launches will be performed in the O&C at KSC, Level I integration for WTR launches will be performed in the OMCF at VAFB after transportation of the integrated Spacelab from the primary launch site (KSC).

The scope of Level I activities is constrained to functional verification of Spacelab/Orbiter hardware and software interface. A final Orbiter Integrated Test will be performed to allow limited "end to end" listing prior to Orbiter stacking with other Shuttle elements.



APPENDIX I-C

ACRONYMS AND ABBREVIATIONS LIST

Å	Angstrom
AAM	Ambient Air Monitor
AC	Alternate Current
ACCEL	Acceleration
AFD	Aft Flight Deck
AMP	Amplifier
ANAL	Analysis
ARC	Ames Research Center
ASSY	Assembly
ATL	Advanced Technology Laboratory
ATT	Attitude
AVG	Average
B/L	Baseline
BLKHD	Bulkhead
BRKT	Bracket
BSHF	Bio Science Holding Facility
BUP	Buildup
C	Centigrade
CA	Combined Astronomy
CACB	Center Aisle Connector Bracket
CB	Canister Bracket
CCTV	Closed Circuit Television
C/D	Controls/Displays
CDMS	Command and Data Management System
cg	Center of Gravity
CITE	Cargo Interface Test Equipment
CM	Centimeter
CMD	Command
C/O	Checkout
CNTR	Control
COAX	Coaxial
CONN	Connector
CORE	Common Operational Research Equipment
CPU	Control Processing Unit
CRT	Cathode Ray Tube
CRYO	Cryogenics
CS	Command/Control System
CTRL	Control
C&W	Caution and Warning

c-3



DbI	Double
DC	Direct Current
DDU	Data Display Unit
DED	Dedicated
DEM0D	Demodulator
DEP	Dependent
DFP	Dedicated Freon Pump
DIA	Diameter
DIFFER	Differential
DIST	Distribution
DWG	Drawing
DYN	Dynamics
E	Engineer
ECG	Electrocardiogram
ECS	Environment Control System
EDP	Experiment Definition Package
EGRET	Explore Gamma Ray Experiment Telescope
EI	End Item
EKG	Electrocardiogram
EL	Electrolite
EMI	Electromagnetic Interference
EOG	Oculographic
EPDB	Experiment Power Distribution Box
EPSP	Experiment Power Switching Panel
ES	Electrical/Environment System
EXP	Experiment
EXPMT	Experiment
FACL	Facility
FILT	Filter
FLT	Flight
FOV	Field of View
FSS	Flight Support System
FSS	Forward Support Structure
FT	Foot, Feet
FUNCT	Function
FURN	Furnish
FWD	Forward
FZR	Freezer
g	Gravity
GE	General Electric
GN ₂	Gaseous Nitrogen
GPR	Ground Processing Requirements
GSE	Ground Support Equipment
GSR	Ground Support Requirements



HDWE	Hardware
HDRM	High Data Rate Multiplexer
HE	Heat Exchanger
He	Helium
HF	Holding Facility
Hr	Hour
HV	High Voltage
Hz	Hertz
ICRS	Intercomm Remote Station
IMU	Inertial Measurement Unit
In	Inch
IND	Independent
INT	Integrated
INVERT	Inverter
INSTAL	Installation
INV/V	Involvement
IR	Infrared
IRU	Inertial Reference Unit
I/O	Input/Output
IPS	Instrument Pointing System
I/S	Interconnect Station
IVT	Intraventricular
JC	Jettison Cable
JSC	Johnson Spaceflight Center
K	Kelvin
Kg	Kilogram
KSC	Kennedy Spaceflight Center
LBNP	Lower Body Negative Pressure
LG	Large
LGHE	Liquid/Gas Heat Exchanger
LHe	Liquid Helium
LN2	Liquid Nitrogen
L/S	Life Science
m	Meter
MEAS	Measure
MECH	Mechanism, Mechanical
MEGRD	Medium Energy Gamma Ray Detector
MET	Metered
Mev	Million Electron Volts
MIC	Multiple Instrument Compartment
MISC	Miscellaneous



mm	Milimeter
MOD	Module
M/P, MP	Manpower
MPF	Multipurpose Furnace
MS	Mass Spectrometer
MSS	Mission Specialist Station
MTRS	Meters
OAF	Orbiter Aft Flight
O&C	Operations and Checkout
OEM	Orbital Environment Monitor
OFLA	Off-line Assembly
ONLA	On-line Assembly
OPF	Orbiter Processing Facility
OPS	Operations
OSC	Oscilloscope
OSCILL	Oscilloscope
PC	Power Cable
PDB	Power Distribution Box
PI	Principal Investigator
P/L	Payload
PMT	Photomultiplier Tube
PNL	Panel
POS	Position
PSS	Payload Special Station
PWR	Power
RAD	Radius
RAU	Remote Acquisition Unit
RBC	Red Blood Cell
RCS	Reaction Control System
RCVR	Receiver
REC	Recorder
Red	Reduction
RESPIR	Respiration
r.f.	Radio Frequency
R.O.	Read Out
SC	Signal Cable
SCINT	Scintillator
SEG	Segment
SHe	Super Critical Helium
SIG	Signal
SIPS	Small Instrument Pointing System
SIRTF	Shuttle Infrared Telescope Facility



S/L	Spacelab
SP	Space Processing
SPAR	Space Processing Application Rocket
SPECT	Spectrometer
SSUS	Solid Spinning Upper Stage
STBD	Starboard
STS	Space Transportation System
SUB	Substitute
SURV	Survey
T	Technician
TDY	Temporary Duty
TELE	Telescope
TLM	Telemetry
TRANS	Transportation
UV	Ultraviolet
VERIF	Verify, Verification
VAC	Voltage Alternating Current
VDC	Voltage Direct Current
XMTR	Transmitter
XPORT	Transport